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MANURIAL TRIALS WITH SUGAR CANE.

S. J. SAINT, M.Sc., Ph.D., F.I.C.

SECTION I.

THE EFFECT OF VARYING COMBINATIONS OF NITROGEN AND POTASH ON THE YIELD OF PLANT CANE. (1930—32).

Previous manurial trials carried out on sugar cane in Barbados have shown that the principal limiting factors affecting the yield of cane grown in the island are water, potash and nitrogen. This trial was therefore planned with the object of determining the effect on the yield of plant cane of varying amounts and combinations of nitrogen and potash.

CENTRES.

Two centres were selected for this trial: (a) a red soil, high rainfall centre and (b) a black soil, medium low rainfall centre.

PLAN.

The trial was laid out in the form of four randomised blocks. There were sixteen treatments which were made up of the various combinations of four different applications of nitrogen and of potash. The varying amounts of nitrogen and potash applied were 0, 40, 80 and 120 lb. per acre, respectively. The size of each plot was 56 cane holes (approximately 1/30 acre) and the inside 42 holes were cut and weighed in the estimation of yield.

RAINFALL.

In view of the importance of water on the yield of cane, it has been thought advisable to record the rainfall data for the two centres for the period December 1930—February 1932, which period covers the growing season. At the black soil centre, the rainfall measured 68.24 inches for the growing period as compared with an average of 58.71 inches for the same months between the years 1890-1929. At the red soil centre, the rainfall was 90.76 inches for the same growing period as compared with an average of 74.44 inches for the same month between the years 1890-1929. The average rainfall figures are taken from the data recorded by Mr. Skeete (Pamphlet No. 9, Dept. of Science and Agriculture, Barbados, 1931, pp. 5-18). Inasmuch as the distribution of the rainfall on the yield of cane is of as great importance as the total amount, the distribution is set out in Figs. 1 and 2.

It will be noted that the growing season under consideration was favoured with a greater rainfall than the average (16.2% and 21.9% for the black and

red soil areas respectively) and that this excess rainfall fell between the months of June and November. The distribution curves show that December was a very dry month and, in consequence, little growth of cane took place subsequent to this.

Manures.

The potash was applied in the form of sulphate of potash in January, about two months after the planting of the cane.

The nitrogen was applied as sulphate of ammonia, at the beginning of July after the rainy season had commenced.

A sample of about 100 lb. cane representative of each treatment was selected in the field during the reaping of the plots and sent in to the chemical laboratory for milling and analysis.

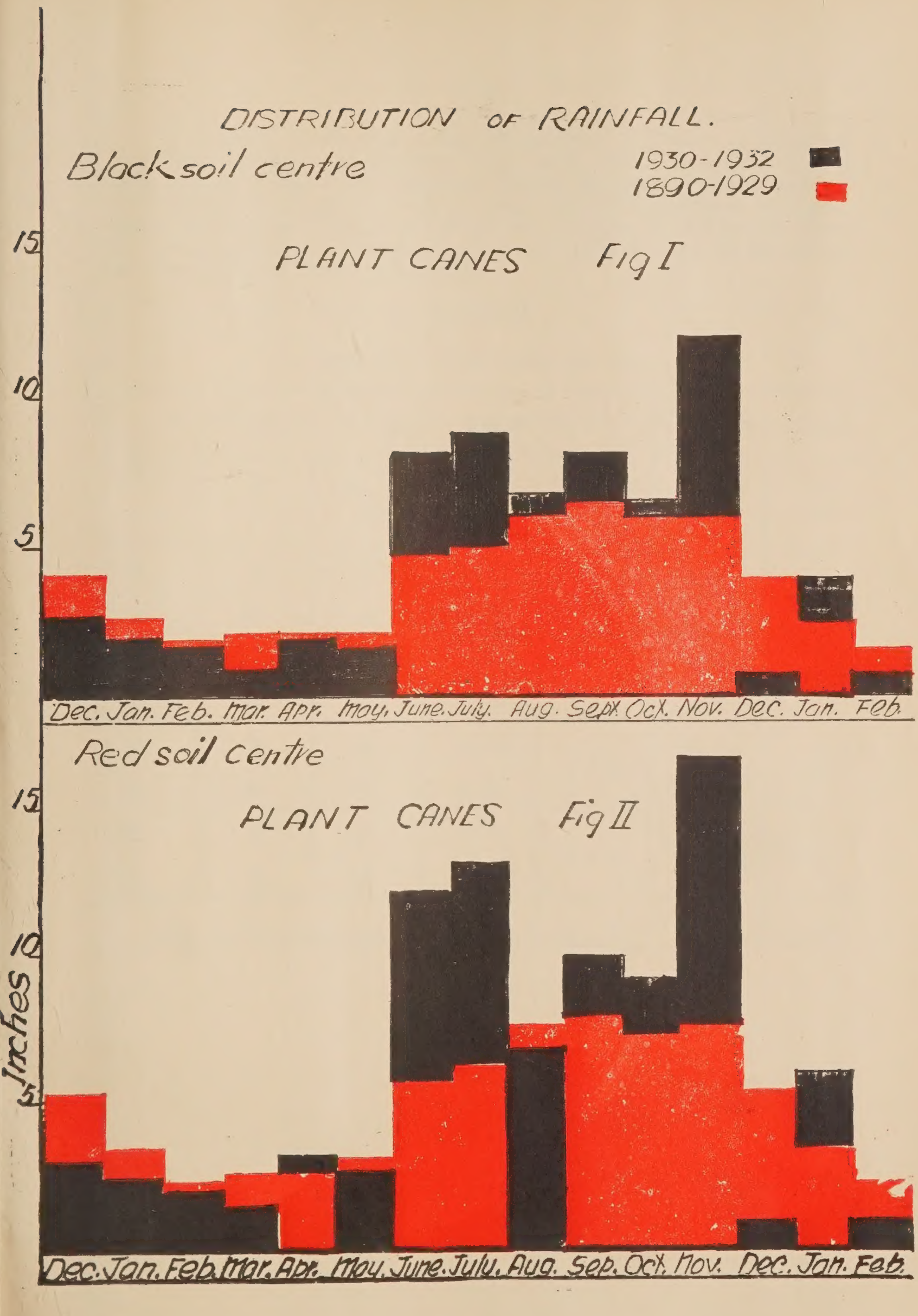
The yield results in terms of tons of cane and sucrose per acre, for the means of four plots of each treatment are set out in Table I.

TABLE I.

Plot No.	Treatment per acre.		Mean yield of 4 plots per acre.			
			Black Soil Centre.		Red Soil Centre.	
	lb. Nitrogen (N)	lb. Potash (K_2O)	Tons Cane.	lb. Sucrose.	Tons Cane.	lb. Sucrose.
1	0	0	45.0	15,865	37.1	14,343
2	40	0	43.6	15,209	36.1	12,779
3	80	0	46.3	15,648	38.3	13,757
4	120	0	47.5	16,403	37.3	13,196
5	0	40	48.9	15,951	39.1	13,621
6	40	40	45.3	16,259	38.9	13,325
7	80	40	46.7	16,163	39.9	14,447
8	120	40	48.7	16,535	39.4	13,596
9	0	80	48.4	16,730	38.3	13,776
10	40	80	49.3	16,196	43.8	16,272
11	80	80	45.8	15,642	41.4	15,156
12	120	80	44.7	15,763	41.2	14,990
13	0	120	44.7	15,526	43.5	15,666
14	40	120	41.7	14,664	43.9	16,525
15	80	120	45.2	14,953	43.9	16,415
16	120	120	45.7	15,802	42.4	15,409

Statistical Analysis.

A difference between the mean yields of 4 plots of 4.3 tons cane for the red soil centre or 7.1 tons cane for the black soil centre has a 20:1 chance of being due to treatment.



DISTRIBUTION OF RAINFALL.
Black soil centre
1930-1932
1890-1929
15
PLANT CANES Fig I
10
5
Dec. Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb.
Red soil centre
15
PLANT CANES Fig II
10
Inches
5
Dec. Jan. Feb. Mar. Apr. May. June. July. Aug. Sep. Oct. Nov. Dec. Jan. Feb.

If the effects on the yield of the different doses of nitrogen or potash are considered separately and the effect, if any, of the other constituent is ignored, it is possible to consider the differences between the means of sixteen plots for each addition of nitrogen or potash and hence add to the precision of the experiment. The yield results are treated in this way in Tables II—VII and the effects of the varying doses of nitrogen and potash on the yield of cane at the two centres are summarised in Tables VIII and IX.

TABLE II.

EFFECT OF 40 lb NITROGEN ON YIELD.

Plot.	Treatments per acre.		Red Soil Centre.		Black Soil Centre.	
	N. lb.	(K_2) lb.	Yield (Tons per acre).	Diff.	Yield (Tons per acre).	Diff.
1	0	0	37.1	—1.0	45.0	—1.4
2	40	0	36.1		43.6	
5	0	40	39.1	—0.2	48.9	—3.6
6	40	40	38.9		45.3	
9	0	80	38.3	+5.5	48.4	+0.9
10	40	80	43.8		49.3	
13	0	120	43.5	+0.4	44.7	—3.0
14	40	120	43.9		41.7	
Difference between means of 16 plots ..				+1.2		—1.8

TABLE III.

EFFECT OF 80 LB. NITROGEN ON YIELD.

Plot.	Treatment per acre. lb. N.	Treatment per acre. lb. K_2O	Red Soil Centre. Yield (Tons per acre).	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre).	Black Soil Centre. Diff.
1	0	0	37.1	+ 1.2	45.0	+ 1.3
3	80	0	38.3		46.3	
5	0	40	39.1	+ 0.8	48.9	— 2.2
7	80	40	39.9		46.7	
9	0	80	38.3	+ 3.1	48.4	— 2.6
11	80	80	41.4		45.8	
13	0	120	43.5	+ 0.4	44.7	+ 0.5
15	80	120	43.9		45.2	
Difference between means of 16 plots.				+ 1.4		— 0.75

TABLE IV.

EFFECT OF 120 LB. NITROGEN ON YIELD.

Plot.	Treatment per acre. lb. N.	Treatment per acre. lb. K_2O	Red Soil Centre. Yield (Tons per acre).	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre).	Black Soil Centre. Diff.
1	0	0	37.1	+ 0.2	45.0	+ 2.5
4	120	0	37.3		47.5	
5	0	40	39.1	+ 0.3	48.9	— 0.2
8	120	40	39.4		48.7	
9	0	80	38.3	+ 2.9	48.4	— 3.7
12	120	80	41.2		44.7	
13	0	120	43.5	— 1.1	44.7	+ 1.0
16	120	120	42.4		45.7	
Difference between means of 16 plots.				+ 0.6		— 0.1

TABLE V.

EFFECT OF 40 LB. POTASH ON YIELD.

Plot.	Treatment per acre. lb. N.	Treatment per acre. lb. K_2O	Red Soil Centre. Yield (Tons per acre).	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre).	Black Soil Centre. Diff.
1	0	0	37.1	+ 2.0	45.0	+ 3.9
5	0	40	39.1		48.9	
2	40	0	36.1	+ 2.8	43.6	+ 1.7
6	40	40	38.9		45.3	
3	80	0	38.3	+ 1.6	46.3	+ 0.4
7	80	40	39.9		46.7	
4	120	0	37.3	+ 2.1	47.5	+ 1.2
8	120	40	39.4		48.7	
Difference between means of 16 plots.				+ 2.1		+ 1.8

TABLE VI.

EFFECT OF 80 LB. POTASH ON YIELD.

Plot.	Treatment per acre. lb. N.	Treatment per acre. lb. K_2O	Red Soil Centre. Yield (Tons per acre).	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre).	Black Soil Centre. Diff.
1	0	0	37.1	+ 1.2	45.0	+ 3.4
9	0	80	38.3		48.4	
2	40	0	36.1	+ 7.7	43.6	+ 5.7
10	40	80	43.8		49.3	
3	80	0	38.3	+ 3.1	46.3	— 0.5
11	80	80	41.4		45.8	
4	120	0	37.3	+ 3.9	47.5	— 2.8
12	120	80	41.2		44.7	
Difference between means of 16 plots.				+ 4.0		+ 1.45

TABLE VII.

EFFECT OF 120 LB. POTASH ON YIELD.

Plot.	Treatment per acre. lb. N.	Treatment per acre. lb. K_2O	Red Soil Centre. Yield (Tons per acre).	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre).	Black Soil Centre. Diff.
1	0	0	37.1	+ 6.4	45.0	— 0.3
13	0	120	43.5		44.7	
2	40	0	36.1	+ 7.8	43.6	— 1.9
14	40	120	43.9		41.7	
3	80	0	38.3	+ 5.6	46.3	— 1.1
15	80	120	43.9		45.2	
4	120	0	37.3	+ 5.1	47.5	— 1.8
16	120	120	42.4		45.7	
Difference between means of 16 plots.				+ 6.2		— 1.3

TABLE VIII.

EFFECT OF VARYING DOSES OF NITROGEN ON YIELD.

Treatment per acre.	Difference from no Nitrogen Plot. (Means of 16 plots). Red Soil Centre.	Difference from no Nitrogen Plot. (Means of 16 plots). Black Soil Centre.
40 lb. Nitrogen	+ 1.2	— 1.8
80 lb. Nitrogen	+ 1.4	— 0.75
120 lb. Nitrogen	+ 0.6	— 0.1

TABLE IX.

EFFECT OF VARYING DOSES OF POTASH ON YIELD.

Treatment per acre.	Difference from no Potash Plot. (Means of 16 plots). Red Soil Centre.	Black Soil Centre.
40 lb. Potash ..	+ 2.1	+ 1.8
80 lb. Potash ..	+ 4.0	+ 1.45
120 lb. Potash..	+ 6.2	— 1.3

Statistical Analysis. Tables II.—IX.

A difference between the mean yields of 16 plots of 2.1 tons for the red soil centre and 3.5 tons for the black soil centre, has a 20:1 chance of being due to treatment.

CONCLUSIONS.

Red Soil Centre.

A consideration of the yield results at the red soil centre shows that the application of nitrogen has had no significant effect on the yield of cane. It is evident that the cane was able to obtain sufficient nitrogen from this soil to make the maximum growth permitted under the other prevailing conditions.

The application of each additional 40 lb. potash per acre at the red soil centre has increased the yield by approximately two tons cane per acre. The effect of potash in increasing the yield of plant cane in ratooning districts has been brought out in previous trials. It has been suggested that this may be due to inadequate potash manuring of ratoons in the general plantation practice.

Black Soil Centre.

A study of the yield results obtained at the black soil centre shows that the land on which this manurial trial was conducted was in such good condition, that the added nitrogen and potash have had no significant effect on the yield of cane. The no-manure plots gave a mean yield of 45 tons cane per acre which is rarely exceeded on the black soils representative of this centre.

SECTION II.

THE YIELD OF RATOONS. (1932—33).

The trials which have been described under Section I. were continued as ratoons in order to determine the residual value, if any, of the sulphate of ammonia and sulphate of potash applied to the plant cane. Since it is the customary plantation practice to manure ratoons, the residual effects of manures applied to the plant cane must serve to increase the yield of the ratooned cane over that obtained by the ordinary ratoon manuring, if this residual value is to have any practical significance.

Treatment.

In view of the above, the ratooned cane was given sulphate of potash at the rate of 100 lb. potash per acre and two different doses of sulphate of ammonia. Blocks I and III received 45 lb. nitrogen per acre and blocks II and IV received 90 lb. nitrogen per acre as sulphate of ammonia. The yields of the ratooned cane are set out in Table X.

RAINFALL.

The rainfall during the growing season April, 1932—March, 1933, was equivalent to 48.79 inches at the black soil centre and 66.6 inches at the red soil centre. The average rainfall figures for the same months for the years 1890—1929 are 50.38 inches for the area represented by the black soil centre and 63.23 inches for the area represented by the red soil centre. The total rainfall therefore approximated very closely to the average figure, but an examination of Figs. 3 and 4 will show that the distribution departed somewhat from the average. The growing season was relatively dry until about October, after which month the rains exceeded the average until the end of January. As a consequence, there was a greater growth of cane during December and January than normally occurs.

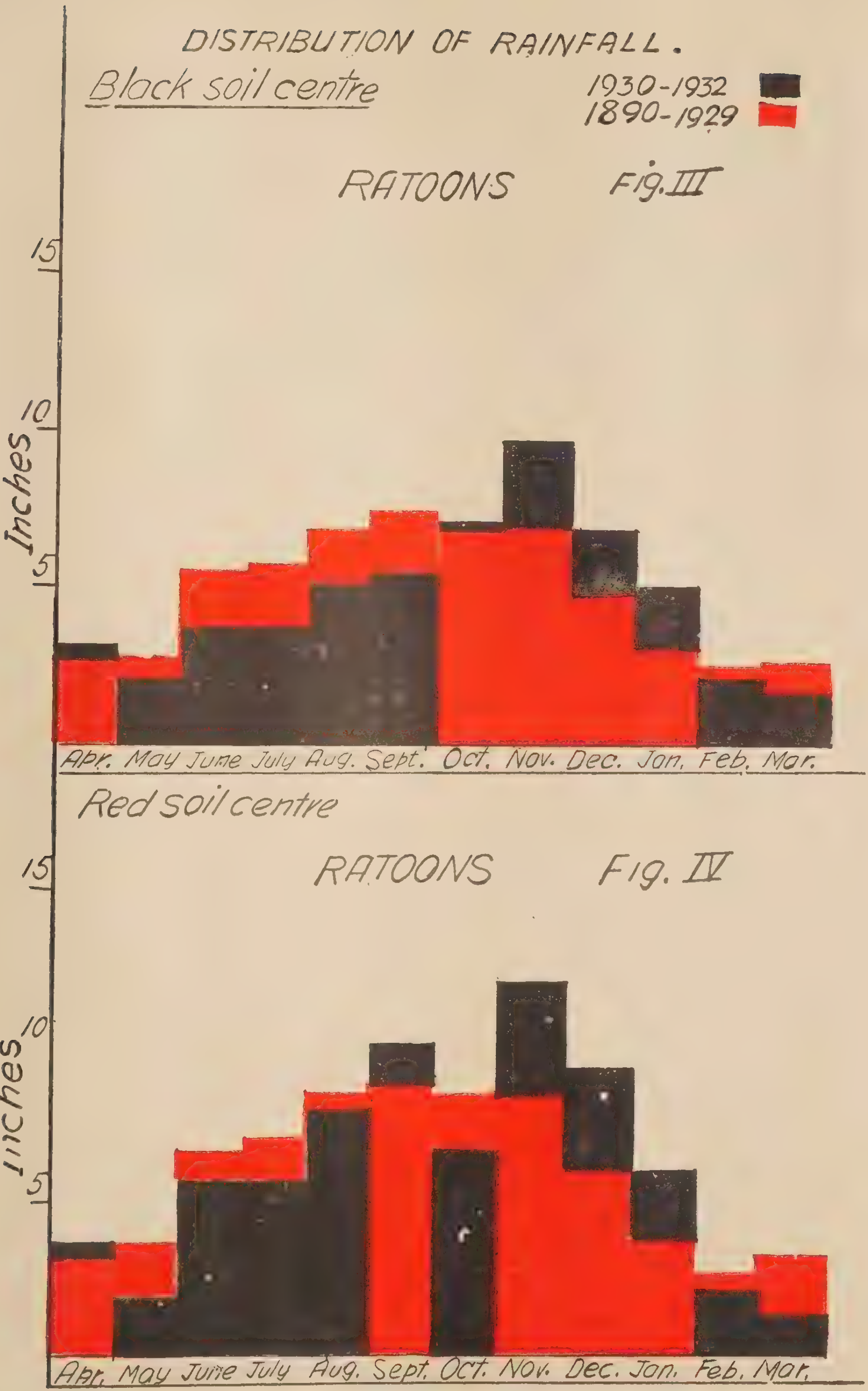

DISTRIBUTION OF RAINFALL.
Black soil centre
1930-1932
1890-1929
RATOONS
Fig. III
15
10
5
Inches
Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar.
Red soil centre
RATOONS
Fig. IV
15
10
5
Inches
Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar.

TABLE X.

Plot.	Treatment per acre. Plant Cane.	Ratoons. Blocks 1 & 3.	Ratoons. Blocks 2 & 4.	Yield of Ratoons. (Means of 2) Red Soil Centre. Blocks 1 & 3 Tons.	Red Soil Centre. Blocks. 2 & 4 Tons.	Black Soil Centre Blocks 1 & 3 Tons.	Black Soil Centre Blocks. 2 & 4 Tons.
1	N_0 K_0	N_4 K_4	N_5 K_4	37.1	45.2	33.4	35.3
2	N_1 K_0	N_4 K_4	N_5 K_4	38.9	43.3	33.3	39.0
3	N_2 K_0	N_4 K_4	N_5 K_4	35.3	43.0	30.6	34.7
4	N_3 K_0	N_4 K_4	N_5 K_4	37.2	40.9	30.6	37.8
5	N_0 K_1	N_4 K_4	N_5 K_4	35.3	44.0	33.2	40.1
6	N_1 K_1	N_4 K_4	N_5 K_4	38.4	41.4	28.9	39.5
7	N_2 K_1	N_4 K_4	N_5 K_4	34.4	43.3	30.1	42.0
8	N_3 K_1	N_4 K_4	N_5 K_4	36.0	45.1	31.4	35.1
9	N_0 K_2	N_4 K_4	N_5 K_4	37.1	39.1	32.3	42 .9
10	N_1 K_2	N_4 K_4	N_5 K_4	33.6	42.5	32.9	35.3
11	N_2 K_2	N_4 K_4	N_5 K_4	35.8	42.7	28.8	37.2
12	N_3 K_2	N_4 K_4	N_5 K_4	35.7	42.1	32.0	40.5
13	N_0 K_3	N_4 K_4	N_5 K_4	41.1	44.5	31.8	37.4
14	N_1 K_3	N_4 K_4	N_5 K_4	38.1	43.4	32.5	32.7
15	N_2 K_3	N_4 K_4	N_5 K_4	39.7	41.4	27.0	36.1
16	N_3 K_3	N_4 K_4	N_5 K_4	87.1	43.8	34.1	37.8
	Means of 32 plots			36.9	42.9	31.4	37.7

Notes on Table X.

N_0 = 0 nitrogen.
N_1 = 40 lb nitrogen per acre as sulphate of ammonia.
N_2 = 80 ,, ,, ,, ,, ,, ,, ,, ,,
N_3 = 120 ,, ,, ,, ,, ,, ,, ,, ,,
N_4 = 45 ,, ,, ,, ,, ,, ,, ,, ,,
N_5 = 90 ,, ,, ,, ,, ,, ,, ,, ,,
K_0 = 0 ,, potash.
K_1 = 40 ,, potash ,, ,, ,, ,, ,, potash
K_2 = 80 ,, ,, ,, ,, ,, ,, ,, ,,
K_3 = 120 ,, ,, ,, ,, ,, ,, ,, ,,
K_4 = 100 ,, ,, ,, ,, ,, ,, ,, ,,

A consideration of the yield data given in Table X indicates that there has been little or no residual effects from the applications of sulphate of ammonia and sulphate of potash which were made to the plant cane. This matter can be considered more exactly if the effects on the yield of the ratoons of the different doses of nitrogen and potash given to the plant cane are considered separately as was done under Section I. The detailed tables are not shown, but the summarised results are given in Tables XI and XII. It is evident from these results that the nitrogen and potash applied to the plant cane has had no significant effect on the yield of the ratoons at either the red soil or the black soil centre.

TABLE XI.

EFFECT OF VARYING DOSES OF NITROGEN ADDED TO PLANT CANE ON YIELD OF RATOONS.

(MEANS OF 8 PLOTS).

Treatment of Plant Canes.	Red Soil Centre. Blocks. 1 & 3 45 lb. N.	Red Soil Centre. Blocks. 2 & 4 90 lb. N.	Black Soil Centre. Blocks. 1 & 3 45 lb. N.	Black Soil Centre. Blocks. 2 & 4 90 lb. N.
40 lb. Nitrogen ..	— 0.4	— 0.6	— 0.8	— 2.3
80 lb. Nitrogen ..	— 1.4	— 0.6	— 3.3	— 1.4
120 lb. Nitrogen ..	— 1.2	— 0.2	— 0.6	-- 1.1

TABLE XII.

EFFECT OF VARYING DOSES OF POTASH ADDED TO PLANT CANE ON YIELD OF RATOONS.

(MEANS OF 8 PLOTS).

Treatment of Plant Canes.	Red Soil Centre. Blocks. 1 & 3 45 lb. N.	Red Soil Centre. Blocks. 2 & 4 90 lb. N.	Black Soil Centre. Blocks. 1 & 3 45 lb. N.	Black Soil Centre. Blocks. 2 & 4 90 lb. N.
40 lb. Potash ..	— 1.1	+ 0.4	— 1.0	+ 2.5
80 lb. Potash ..	— 1.6	— 1.5	— 0.5	+ 2.3
120 lb. Potash ..	+ 1.9	+ 0.2	— 0.6	— 0.7

Statistical Analysis of Tables XI and XII.

A difference between the mean yields of 5 plots of 2.8 tons for the red soil centre and 2.9 tons for the black soil centre has a 20:1 chance of being due to treatment.

It was shown in Section I that the plant cane growing at both the red soil and black soil centres did not show any significant responses to the application of nitrogen as sulphate of ammonia. This indicated that the soil reserves of nitrogen were sufficient to grow the maximum crop under the other conditions of the experiment.

A consideration of the mean yields of the ratoons grown on Blocks I and III and on Blocks II and IV shows that there is a big difference between the effects of 45 lb. nitrogen and 90 lb. nitrogen per acre, as sulphate of ammonia, on the yield of the ratoons. This information has been summarised in Table XIII, where it will be seen that the additional 45 lb. nitrogen per acre, as sulphate of ammonia, increases the yield of the ratoons by 6 tons cane per acre.

TABLE XIII.

EFFECT OF 45 LB. NITROGEN AND 90 LB. NITROGEN AS SULPHATE OF AMMONIA ON YIELD OF RATOONS.

Treatment per acre.	Yield of Cane (per acre). (Means of 32 plots).	
	Red Soil Centre.	Black Soil Centre.
	Tons.	Tons.
100 lb. Potash + 90 lb. Nitrogen	42.9	37.7
100 lb. Potash + 45 lb. Nitrogen	36.9	31.4
Difference	+ 6.0	+ 6.3

Statistical Analysis.

A difference between the mean yields of 32 plots of 1.4 tons for the red soil centre and 1.45 tons for the black soil centre has a 20:1 chance of being due to treatment.

Referring again to Tables VIII and XI, it is seen that applications of 40, 80 and 120 lb. nitrogen per acre, as sulphate of ammonia, had no effect on the yield of plant cane nor any residual effect on the yield of the following ratoons. The data set forth in Table XIII, however, shows that the yield of ratooned cane which only received 45 lb. nitrogen per acre, was definitely limited by a deficiency of nitrogen. The conclusion must therefore be drawn that, on the coral limestone soils of Barbados, large additions of nitrogen as sulphate of ammonia, to the plant cane, will have little, if any, residual effect on the yield of the following crop of ratoons, even though the ratooned cane is suffering from a shortage of nitrogen.

This conclusion brings more evidence to bear, in support of a recommendation which has been previously made from the results of other manurial trials carried out in Barbados. These results have indicated that it is not economical to follow the common plantation practice of manuring plant cane heavily in order to benefit the yield of the following ratoon crops. It is a better practice to give the plant cane only what it needs as manure and then to manure each ratoon crop adequately as it comes along.

SECTION III.

THE EFFECT OF VARYING COMBINATIONS OF POTASH AND NITROGEN ON THE YIELD OF RATOONS. (1932—33).

This trial was planned in a similar manner to the trial described under Section 1, except that the treatments were applied to a crop of second ratoon cane which had been manured as plant cane and as first ratoons by the plantation.

The plantation manuring of these canes per acre was as follows:—

Plant Canes.

Before Planting—4 squares Pen Manure. (approximately 30 tons).

In February—149 lb. equal parts Sulphate of Ammonia and Muriate of Potash.

In June—280 lb. Sulphate of Ammonia.

First Ratoons.

In May—224 lb. equal parts Sulphate of Ammonia and Muriate of Potash.
In June—224 lb. Sulphate of Ammonia.
In August—224 lb. Sulphate of Ammonia.

The yields of cane and sucrose for the second ratoons together with the manurial treatment are set out in Table XIV. For the sucrose determinations, two samples of about 100 lb. cane representative of each plot were selected in the field from different blocks. These samples were ground in the experimental mill, the juice and megass were analysed and the composition of the cane was calculated from the analytical figures.

RAINFALL.

The rainfall during the growing season April, 1932—March, 1933, was equivalent to 81.9 inches. The average rainfall figure for the same months for the years 1890—1929 is 75.15 inches for the area representative of this centre, although this centre normally has a higher rainfall than the other stations in this area from which rainfall data are recorded. It can therefore be stated that the rainfall approximated to the average during the growing season under discussion. The distribution of the rainfall as compared to the average was similar to that shown in Fig. 4.

The experiment was laid out in the form of randomised blocks with four replicates of each treatment.

TABLE XIV.

Plot No.	Treatment per acre.		Mean Yield of 4 Replicates per acre.	
	lb. Nitrogen (N)	lb. Potash (K_2O)	Tons Cane.	Tons Sucrose.
1	0	0	36.4	5.86
2	40	0	38.1	6.06
3	80	0	38.4	5.96
4	120	0	40.4	6.32
5	0	40	35.3	5.61
6	40	40	36.3	5.64
7	80	40	36.5	5.68
8	120	40	37.5	5.88
9	0	80	36.2	5.66
10	40	80	37.2	6.11
11	80	80	37.7	5.92
12	120	80	38.8	6.37
13	0	120	34.3	5.54
14	40	120	36.4	5.89
15	80	120	38.7	6.35
16	120	120	38.3	5.90

Statistical Analysis.

A difference between the mean yields of 4 plots of 4.6 tons cane per acre has a 20:1 chance of being due to treatment.

No conclusions of any significance can be drawn from a study of the results given in Table I. As in the previous section, the effect of the different doses of nitrogen and potash can be studied more exactly if the effect of each constituent is examined separately. This has been done in Tables XV and XVI where it can be seen that the varying doses of potash have had no effect on the yield of cane, whereas the applications of 80 and 120 lb. nitrogen per acre have given significant increases in the yield of cane.

TABLE XV.

EFFECT OF VARYING AMOUNTS OF NITROGEN ON YIELD.

Treatment per acre. lb. Nitrogen (N.)	Treatment per acre. lb. Potash (K_2O)	Yield. (Tons Cane).	Difference between means of 4 plots.	Difference between means of 16 plots.
EFFECT OF 40 LB. NITROGEN.				
0	0	36.4	+ 1.7	+ 1.6
40	0	38.1		
0	40	35.3	+ 1.0	
40	40	36.3		
0	80	36.2	+ 1.5	
40	80	37.7		
0	120	34.3	+ 2.1	
40	120	36.4		

TABLE XV—(*Continued*).

EFFECT OF VARYING AMOUNTS OF NITROGEN ON YIELD.

Treatment per acre. lb. Nitrogen (N.)	Treatment per acre. lb. Potash K_2O	Yield (Tons Cane).	Difference between means of 4 plots.	Difference between means of 16 plots.
EFFECT OF 80 LB. NITROGEN.				
0	0	36.4	+ 2.0	+ 2.3
80	0	38.4		
0	40	35.3	+ 1.2	
80	40	36.5		
0	80	36.2	+ 1.5	
80	80	37.7		
0	120	34.3	+ 4.4	
80	120	38.7		
EFFECT OF 120 LB. NITROGEN				
0	0	36.4	+ 4.0	+ 3.2
120	0	40.4		
0	40	35.3	+ 2.2	
120	40	37.5		
0	80	36.2	+ 2.6	
120	80	38.8		
0	120	34.3	+ 4.0	
120	120	38.3		

TABLE XVI.

EFFECTS OF VARYING AMOUNTS OF POTASH ON THE YIELD.

Treatment per acre. lb. Nitrogen (N.)	lb. Potash. (K_2O)	Yield (Tons Cane).	Difference between means of 4 plots	Difference between means of 16 plots.
EFFECT OF 40 LB. K_2O				
0	0	36.4	— 1.1	— 1.9
0	40	35.3		
40	0	38.1	— 1.8	
40	40	36.3		
80	0	38.4	— 1.9	
80	40	36.5		
120	0	40.4	— 2.9	
120	40	37.5		
EFFECT OF 80 LB. K_2O				
0	0	36.4	— 0.2	— 0.7
0	80	36.2		
40	0	38.1	— 0.4	
40	80	37.7		
80	0	38.4	— 0.7	
80	80	37.7		
120	0	40.4	— 1.6	
120	80	38.8		

TABLE XVI—(*Continued*).

EFFECTS OF VARYING AMOUNTS OF POTASH ON THE YIELD.

Treatment per acre. lb. Nitrogen (N.)	Treatment per acre. lb. Potash (K_2O)	Yield (Tons Cane).	Difference between means of 4 plots.	Difference between means of 16 plots.
EFFECT OF 120 LB. K_2O				
0	0	36.4	— 2.1	— 1.4
0	120	34.3		
40	0	38.1	— 1.7	
40	120	36.4		
80	0	38.4	+ 0.3	
80	120	38.7		
120	0	40.4	— 2.1	
120	120	38.3		

Statistical Analysis for Tables XV and XVI.

A difference between the means of 4 plots of 4.6 tons per acre and a difference between the means of 16 plots of 2.3 tons per acre, has a 20:1 chance of being due to treatment.

EFFECT OF NITROGEN AND POTASH MANURING ON SUCROSE CONTENT OF RATOONED CANE.

The effect of the varying doses of nitrogen and potash on the sucrose content of the juice of the ratoons is set out in Tables XVII and XVIII.

TABLE XVII.

EFFECT OF VARYING AMOUNTS OF NITROGEN ON PER CENT. SUCROSE IN JUICE.

Treatment per acre. lb. Nitrogen (N)	Treatment per acre. lb. Potash (K_2O)	Per cent. Sucrose in Juice.	Difference between means of 2 plots.	Difference between means of 8 plots.
EFFECT OF 40 lb NITROGEN.				
0	0	19.83	— 0.27	— 0.19
40	0	19.56		
0	40	19.83	— 0.36	
40	40	19.47		
0	80	19.61	— 0.03	
40	80	19.58		
0	120	20.01	—0.11	
40	120	19.90		
EFFECT OF 80 lb NITROGEN.				
0	0	19.83	— 0.54	— 0.38
80	0	19.29		
0	40	19.83	— 0.40	
80	40	19.43		
0	80	19.61	— 0.47	
80	80	19.14		
0	120	20.01	— 0.10	
80	120	19.91		

TABLE XVII—(*Continued*).

EFFECT OF VARYING AMOUNTS OF NITROGEN ON PER CENT. SUCROSE IN JUICE.

Treatment per acre. lb. Nitrogen (N.)	Treatment per acre. lb. Potash (K_2O)	Per cent. Sucrose in Juice.	Difference between means of 2 plots.	Difference between means of 8 plots.
EFFECT OF 120 lb NITROGEN.				
0	0	19.83	— 0.53	— 0.63
120	0	19.30		
0	40	19.83	— 0.65	
120	40	19.18		
0	80	19.61	— 0.43	
120	80	19.18		
0	120	20.01	— 0.89	
120	120	19.12		

TABLE XVIII.

EFFECT OF VARYING AMOUNTS OF POTASH ON PER CENT SUCROSE IN JUICE.

Treatment per acre. lb. Nitrogen (N)	Treatment per acre. lb. Potash (K_2O)	Per cent. Sucrose in Juice.	Difference between means of 2 plots.	Difference between means of 8 plots.
EFFECT OF 40 LB. POTASH.				
0	0	19.83	0	— 0.02
0	40	19.83		
40	0	19.56	— 0.09	
40	40	19.47		
80	0	19.29	+ 0.14	
80	40	19.43		
120	0	19.30	— 0.12	
120	40	19.18		

TABLE XVIII—(*Continued*).

EFFECT OF VARYING AMOUNTS OF POTASH ON PER CENT. SUCROSE IN JUICE.

Treatment, per acre. lb. Nitrogen (N.)	lb. Potash (K_2O)	Per cent. Sucrose in Juice.	Difference between means of 2 plots.	Difference between means of 8 plots.
EFFECT OF 80 LB. POTASH.				
0	0	19.83	— 0.22	— 0.12
0	80	19.61		
40	0	19.56	+ 0.02	
40	80	19.58		
80	0	19.29	— 0.15	
80	80	19.14		
120	0	19.30	— 0.12	
120	80	19.18		
EFFECT OF 120 LB. POTASH.				
0	0	19.83	+ 0.18	+ 0.24
0	120	20.01		
40	0	19.56	+ 0.34	
40	120	19.90		
80	0	19.29	+ 0.62	
80	120	19.91		
120	0	19.30	— 0.18	
120	120	19.12		

A study of the figures given in Table XVII. shows that the increasing doses of nitrogen as sulphate of ammonia to these ratoons has had a definite depressing effect on the percentage of sucrose in the juice of the cane. It is interesting to note the counteracting effect which potash manuring appears to exert. In the case of the dose of 40 lb. nitrogen per acre, both the applications of 80 and 120 lbs. of potash per acre have apparently prevented the nitrogenous dressing from depressing the percentage of sucrose in the juice. In the 80 lb. dose of nitrogen per acre, only the 120 lb. dose of potash has had this effect. In the 120 lb. dose of nitrogen, none of the potash dressings has had any effect on the depressing action of the nitrogenous manuring.

In view of the facts that an increased nitrogenous manuring has increased the tonnage of cane, but has decreased the percentage sucrose in the juice of these ratoons, it is of interest to examine the effect of the nitrogenous manuring on the actual yield of sucrose per acre. The summarised data is given in Table XIX.

TABLE XIX.

EFFECT OF VARYING AMOUNTS OF NITROGEN ON THE YIELD OF SUCROSE FROM RATOONS.

Treatment per acre	Increased Yield Over No Manure Plot.		Ratio Tons Cane / Tons Sucrose
	Tons Cane per acre	Tons Sucrose per acre	
40 lb Nitrogen	+ 1.6	+ 0.26	6.15
80 lb "	+ 2.3	+ 0.31	7.42
120 lb "	+ 3.2	+ 0.45	7.11

These experiments indicate that the ratio of potash to nitrogen used in the manuring of ratoon cane has an important bearing on the sucrose content of the cane. High nitrogenous manuring of ratoons should be accompanied by high potash manuring, if the increased tonnage of cane yielded by the nitrogenous manuring is to be followed by a proportionate increase in sucrose per acre.

SECTION IV.

THE EFFECT OF PEN MANURE ON THE YIELD OF PLANT CANE IN THE PRESENCE AND ABSENCE OF NITROGEN AND POTASH. (1930-32).

The object of this experiment was to compare the effect on the yield of plant cane of varying dressings of pen manure, a simple mixture of artificial manures and of the addition of artificial manures to pen manure.

Centres.

Two centres were selected for this trial (a) a red soil, high rainfall centre and (b) a black soil, medium low rainfall centre.

Rainfall.

The rainfall conditions at these centres corresponded very closely to the conditions already outlined for the red and black soil centres in Section I. and reference should be made to this section for fuller details. It need only be repeated here that the rainfall for the growing season 1930-32 was between 16% and 20% above the average.

Plan.

The trial was laid out in the form of four randomised blocks. There were sixteen different treatments which are shown in detail in Table XX. The size of each plot was 56 cane holes (approximately 1/30 acre) and the inside 42 holes were cut and weighed in the estimation of yield.

Manures.

The pen manure was applied in late November on the surface as a mulch soon after the cane had been planted. The plots which were not mulched with pen manure were covered down with trash. The potash was applied as sulphate of potash in January and the nitrogen was given as sulphate of ammonia at the beginning of July after the rainy season had commenced.

The yield results in terms of tons of cane per acre for the means of the four plots of each treatment are given in Table XX.

TABLE XX.

Plot No.	Treatment per acre. Pen Manure Tons.	Nitrogen (N) lb.	Potash (K_2O) lb.	Mean Yield of 4 Plots (Tons per acre). Red Soil Centre.	Black Soil Centre.
$P_0\ N_0\ K_0$	0	0	0	32.5	37.3
$P_0\ N_0\ K_1$	0	0	100	36.4	38.3
$P_0\ N_1\ K_0$	0	60	0	40.0	40.6
$P_0\ N_1\ K_1$	0	60	100	43.3	43.1
$P_1\ N_0\ K_0$	10	0	0	40.6	35.8
$P_1\ N_0\ K_1$	10	0	100	44.8	37.2
$P_1\ N_1\ K_0$	10	60	0	38.5	38.0
$P_1\ N_1\ K_1$	10	60	100	40.5	39.6
$P_2\ N_0\ K_0$	20	0	0	40.6	38.4
$P_2\ N_0\ K_1$	20	0	100	41.5	36.9
$P_2\ N_1\ K_0$	20	60	0	40.6	40.4
$P_2\ N_1\ K_1$	20	60	100	47.0	40.4
$P_3\ N_0\ K_0$	30	0	0	40.2	38.0
$P_3\ N_0\ K_1$	30	0	100	44.5	39.8
$P_3\ N_1\ K_0$	30	60	0	41.9	41.5
$P_3\ N_1\ K_1$	30	60	100	46.9	41.7

Statistical Analysis.

A difference between mean yields of 4 plots of 5.2 tons per acre for the red soil centre and 4.5 tons per acre for the black soil centre has a 20:1 chance of being due to treatment.

The various deductions which may be drawn from the trial are best brought out by considering the various factors separately.

In Table XXI the effects of the various dressings of pen manure on the yield are shown and it will be seen that, at the red soil centre the effect on the yield of 10, 20 and 30 tons pen manure is very similar. Under the conditions of the experiment each of these various applications of pen manure has increased the yield by about 8.0 tons cane per acre. At the black soil centre, the pen manure has had no effect on the yield. In this drier area, the plant cane was evidently unable to utilise the nutrients in the pen manure which, as at the red soil centre, had been applied as a mulch.

TABLE XXI.

EFFECT OF PEN MANURE ON YIELD.

Plot Numbers.	Red Soil Centre. Yield (Tons per acre.)	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre.)	Black Soil Centre. Diff.
P_0 K_0 N_0	32.5	+ 8.1	37.3	− 1.5
P_1 K_0 N_0	40.6		35.8	
P_0 K_0 N_0	32.5	+ 8.1	37.3	+ 1.1
P_2 K_0 N_0	40.6		38.4	
P_0 K_0 N_0	32.5	+ 7.7	37.3	+ 0.7
P_3 K_0 N_0	40.2		38.0	

In Table XXII. the value of 60 lb. nitrogen per acre as sulphate of ammonia on the yield of cane is considered. At the red soil centre, this nitrogen appears to have increased the yield by about 7 tons per acre and, at the black soil centre, by about 4 tons per acre.

TABLE XXII.

EFFECT OF 60 LB. NITROGEN PER ACRE AS SULPHATE OF AMMONIA.

Plot Numbers.	Red Soil Centre.		Black Soil Centre.	
	Yield (Tons per acre.)	Diff.	Yield (Tons per acre.)	Diff.
P_0 K_0 N_0	32.5	+ 7.5	37.3	+ 3.3
P_0 K_0 N_1	40.0		40.6	
P_0 K_1 N_0	36.4	+ 6.9	38.3	+ 4.8
P_0 K_1 N_1	43.3		43.1	

In Table XXIII the effect of 60 lb. nitrogen as sulphate of ammonia on the yield is considered when applied to cane previously treated with pen manure. It will be noted that at the red soil centre there is no response to the additional nitrogen applied which indicates that the cane was able to obtain all the nitrogen which it needed from the pen manure. At the black soil centre, as would be expected from the results recorded in Tables XXI and XXII, the plant cane has responded to the application of sulphate of ammonia.

TABLE XXIII.

EFFECT OF NITROGEN IN THE PRESENCE OF PEN MANURE.

Plot Numbers.	Red Soil Centre.		Black Soil Centre.	
	Yield (Tons per acre.)	Diff.	Yield (Tons per acre.)	Diff.
P_1 K_0 N_0	40.6	− 2.1	35 8	+ 2.2
P_1 K_0 N_1	38.5		38.0	
P_2 K_0 N_0	40.6	0	38.4	+ 2.0
P_2 K_0 N_1	40.6		40.4	
P_3 K_0 N_0	40.2	+ 1.7	38.0	+ 3.5
P_3 K_0 N_1	41.9		41.5	
Mean of 12 plots		− 0.1		+ 2.6

In Table XXIV the effect of 100 lb. potash per acre as sulphate of potash, on the yield of cane is shown. It will be noted that at the red soil centre the addition of this amount of potash has increased the yield by about 3½ tons cane per acre indicating once again the effect of potash in increasing the yield of plant cane in ratooning districts. At the black soil centre the increased yield of 1¾ tons of cane as a result of potash manuring cannot be regarded as significant.

TABLE XXIV.

EFFECT OF 100 LB. POTASH PER ACRE AS SULPHATE OF POTASH.

Plot Numbers.	Red Soil Centre. Yield (Tons per acre)	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre.)	Black Soil Centre. Diff.
P_0 K_0 N_0	32.5	+ 3.9	37.3	+ 1.0
P_0 K_1 N_0	36.4		38.3	
P_0 K_0 N_1	40.0	+ 3.3	40.6	+ 2.5
P_0 K_1 N_1	43.3		43.1	

In Table XXV the effect on the yield of 100 lb. potash, as sulphate of potash is considered when applied to land previously treated with pen manure. It will be noted that, at the red soil centre the potash has increased the yield of cane by about 3 tons per acre or by an increase which is similar to that obtained without pen manure. It would therefore appear that when applied to plant cane, as in this experiment, the potash in pen manure does not become sufficiently available during the growing season to make up for a deficiency of this ingredient in the soil. This is of special interest in that it has been shown that the nitrogen in the pen manure at this centre became available and was able to satisfy the need of the plant cane for nitrogen. As would be expected from the results shown in Table XXIV., the sulphate of potash applied in addition to pen manure at the black soil centre has had no effect on the yield.

TABLE XXV.

EFFECT OF 100 LB. POTASH IN PRESENCE OF PEN MANURE.

Plot Numbers.	Red Soil Centre. Yield (Tons per acre.	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre.	Black Soil Centre. Diff.
P_1 K_0 N_0	40.6	+ 4.2	35.8	+ 1.4
P_1 K_1 N_0	44.8		37.2	
P_2 K_0 N_0	40.6	+ 0.9	38.4	− 1.5
P_2 K_1 N_0	41.5		36.9	
P_3 K_0 N_0	40.2	+ 4.3	38.0	+ 1.8
P_3 K_1 N_0	44.5		39.8	
Mean of 12 plots		+ 3.1		+ 0.6

In Table XXVI the effect on the yield of 60 lb. nitrogen as sulphate of ammonia and 100 lb. potash as sulphate of potash is considered. It will be noted that at the red soil centre the application of nitrogen and potash has increased the yield by 10.8 tons cane which is as big an increase as was obtained by the various dressings of pen manure. (See Table XXI). At the black soil centre, the dressings of nitrogen and potash have increased the yield by about 6 tons cane per acre, which shows conclusively that, since the applications of pen manure had no effect on the yield, the nutrients in the pen manure did not become available to the plant.

TABLE XXVI.

EFFECT OF 60 LB. NITROGEN AND 100 LB. POTASH ON YIELD.

Plot Numbers.	Red Soil Centre. Yield (Tons per acre.)	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre.)	Black Soil Centre. Diff.
P_0 K_0 N_0	32.5	+ 10.8	37.3	+ 5.8
P_0 K_1 N_1	43.3		43.1	

In Table XXVII the effect of the dressings of nitrogen and potash are considered when applied in addition to pen manure. At the red soil centre there appears to be an increased yield of about 4 tons cane per acre as a result of applying the mixture of artificials to the pen manure. At the black soil centre, there is an increased yield of about 3 tons cane per acre. From a consideration of the results already discussed (see Tables XXIII and XXV), it would appear that, at the red soil centre, the increased yield is due to the sulphate of potash in the artificial mixture; at the black soil centre where there was apparently no potash deficiency, the increased yield is due to the sulphate of ammonia.

TABLE XXVII.

EFFECT OF NITROGEN AND POTASH IN PRESENCE OF PEN MANURE.

Plot Numbers.	Red Soil Centre. Yield (Tons per acre.)	Red Soil Centre. Diff.	Black Soil Centre. Yield (Tons per acre.)	Black Soil Centre. Diff.
P_1 K_0 N_0	40.6	− 0.1	35.8	+ 3.8
P_1 K_1 N_1	40.5		39.6	
P_2 K_0 N_0	40.6	+ 6.4	38.4	+ 2.0
P_2 K_1 N_1	47.0		40.4	
P_3 K_0 N_0	40.2	+ 6.7	38.0	+ 3.7
P_2 K_1 N_1	46.9		41.7	
Mean of 12 plots		+ 4.3		+ 3.2

SECTION V.

THE YIELD OF RATOONS (1932—33).

The trial at the black soil centre described under Section IV was continued as ratoons. Unfortunately, it was not possible to continue the plots at the red soil centre as ratoons.

TREATMENT.

As has been customary in the past, the ratooned cane was manured as is done in general plantation practice. As soon as possible after the reaping of the plant cane, a dressing of sulphate of potash at the rate of 100 lb. potash per acre was given to all plots. Two different doses of nitrogen, as sulphate of

ammonia, were given when the rains commenced. Blocks 1 and 3 received 45 lb. nitrogen per acre and Blocks 2 and 4 received 90 lb. nitrogen per acre. The yields of the ratooned cane are set out in Table XXVIII.

RAINFALL.

The rainfall during the growing season, April 1932—March 1933, was equivalent to 48.71 inches and the distribution was very similar to that of the black soil centre described under Section II. As pointed out in Section II this rainfall approximates very closely to the average for the past 40 years, but the rains commenced later than usual and continued later.

TABLE XXVIII.

Treatment per acre.			Yield of Ratoons. (Tons per acre) (Means of 2.)	
Plant Cane.	Ratoons.			
	Blocks 1 and 3.	Blocks 2 and 4.	Blocks 1 and 3.	Blocks 2 and 4.
P_0 N_0 K_0	N_2 K_1	N_3 K_1	23.5	26.7
P_0 N_0 K_1	N_2 K_1	N_3 K_1	20.8	30.2
P_0 N_1 K_0	N_2 K_1	N_3 K_1	26.8	28.5
P_0 N_1 K_1	N_2 K_1	N_3 K_1	22.6	28.5
P_1 N_0 K_0	N_2 K_1	N_3 K_1	21.9	29.8
P_1 N_0 K_1	N_2 K_1	N_3 K_1	24.7	28.4
P_1 N_1 K_0	N_2 K_1	N_3 K_1	26.7	31.2
P_1 N_1 K_1	N_2 K_1	N_3 K_1	27.5	32.5
P_2 N_0 K_0	N_2 K_1	N_3 K_1	25.9	29.9
P_2 N_0 K_1	N_2 K_1	N_3 K_1	20.3	30.4
P_2 N_1 K_0	N_2 K_1	N_3 K_1	24.2	28.8
P_2 N_1 K_1	N_2 K_1	N_3 K_1	21.6	30.0
P_3 N_0 K_0	N_2 K_1	N_3 K_1	29.1	32.1
P_3 N_0 K_1	N_2 K_1	N_3 K_1	21.8	32.6
P_3 N_1 K_0	N_2 K_1	N_3 K_1	28.1	30.2
P_3 N_1 K_1	N_2 K_1	N_3 K_1	22.8	30.1
Means of	32 plots		24.3	30.0

Statistical Analysis.

A difference between mean yields of 2 plots of 7.0 tons per acre has a 20:1 chance of being due to treatment.

EFFECT OF 45 lb AND 90 lb NITROGEN AS SULPHATE OF AMMONIA.

The most striking result of the yields set out in Table XXVIII is the difference in the mean yields of Blocks 1 and 3 and Blocks 2 and 4. The additional application of 45 lb. nitrogen as sulphate of ammonia to Blocks 2 and 4 has increased the yield of cane by 5.7 tons per acre. This result is very similar to the results obtained for the ratoons dealt with in Section II. It is evident that ratoon cane needs a rapidly acting nitrogenous manure to effect its maximum growth and that the equivalent of 45 lb. nitrogen per acre is insufficient in a year of average rainfall.

RESIDUAL EFFECT OF PEN MANURE.

It was shown in the previous section that, at this black soil centre, the nutrients in the pen manure applied to the plant cane had not become sufficiently avilable, during the growing season, to have any effect on the yield. It might therefore be expected that there would be a marked residual effect of this pen manure on the yield of the ratoons.

The residual value of the pen manure on the yield of the ratoons is set out in Table XXIX. where the mean of all blocks is given and also the mean of the blocks treated with 45 lb. and 90 lb. nitrogen respectively.

TABLE XXIX.

RESIDUAL VALUE OF PEN MANURE ON YIELD OF RATOONS.

Treatment of Plant Canes.	Blocks 1 and 3.		Blocks 2 and 4.	
10 Tons Pen Manure.	Yield of Ratoons.	Diff.	Yield. of Ratoons.	Diff.
P_0 K_0 N_0	23.5	− 1.6	26.7	+ 3.1
P_1 K_0 N_0	21.9		29.8	
P_0 K_1 N_0	20.8	+ 3.9	30.2	− 1.8
P_1 K_1 N_0	24.7		28.4	
P_0 K_0 N_1	26.8	− 0.1	28·5	+ 2.7
P_1 K_0 N_1	26.7		31.2	
P_0 K_1 N_1	22.6	+ 4.9	28.5	+ 4.0
P_1 K_1 N_1	27.5		32.5	
Mean of 8 plots Mean of 16 plots	= + 1.9	+ 1.8 tons per acre		+ 2.0

TABLE XXIX.

RESIDUAL VALUE OF PEN MANURE ON YIELD OF RATOONS.

Treatment of Plant Canes.	Blocks 1 and 3.		Blocks 2 and 4.	
20 Tons Pen Manure.	Yield of Ratoons.	Diff.	Yield of Ratoons.	Diff.
P_0 K_0 N_0	23.5	+ 2.4	26.7	+ 3.2
P_2 N_0 N_0	25.9		29.9	
P_0 K_1 N_0	20.8	– 0.5	30.2	+ 0.2
P_2 K_1 N_0	20.3		30.4	
P_0 K_0 N_1	26.8	– 2.6	28.5	+ 0.3
P_2 K_0 N_1	24.2		28.8	
P_0 K_1 N_1	22.6	– 1.0	28.5	+ 1.5
P_2 K_1 N_1	21.6		30.0	
Mean of 8 plots Mean of 16 plots	= +0.4 tons	– 0.4 per acre		+ 1.3
30 Tons Pen Manure.				
P_0 K_0 N_0	23.5	+ 5.6	26.7	+ 5.4
P_3 K_0 N_0	29.1		32.1	
P_0 K_1 N_0	20.8	+ 1.0	30.2	+ 2.4
P_3 K_1 N_0	21.8		32. 6	
P_0 K_0 N_1	26.8	+ 1.2	28.5	+ 1.7
P_3 K_0 N_1	28.1		30.2	
P_0 K_1 N_1	22.6	+ 0.2	28.5	+ 1.6
P_3 K_1 N_1	22.8		30.1	
Mean of 8 plots Mean of 16 plots	= + 2.4 tons	+ 2.0 per acre		+ 2.8

Statistical Analysis to Table XXIX.

A difference between mean yields of 8 plots of 3.5 tons per acre and between mean yields of 16 plots of 2.5 tons per acre, has a 20:1 chance of being significant.

The increased yields of 1.9 tons and 0.4 tons cane which are due to the residual value of the 10 and 20 tons pen manure applied to the plant cane can scarcely be regarded as significant. The increase in yield of the ratoons of 2½ tons cane due to the residual value of 30 tons pen manure applied to the plant cane is very probably a significant increase. The actual increase in yield of the ratoons, however, considering the negative effect of the pen manure on the plant cane is very small.

If the relative residual effects of the pen manure on Blocks 1 and 3 and Blocks 2 and 4 are compared, it will be seen that they are very similar. This is somewhat surprising in view of the big response of the ratoons on Blocks 2 and 4 to the extra 45 lb. nitrogen per acre which they received as sulphate of ammonia. These results confirm those obtained and reported on in Section II. It would appear that ratoon cane needs its nitrogen in a readily available form if the maximum benefits in yield are to be obtained. Pen manure applied to the plant cane does not apparently supply sufficient available nitrogen to the following ratoon cane to permit of the maximum yield being obtained.

SUMMARY.

The most important conclusions which may be derived from the manurial trials reported on in this paper may be summarised as follows:—

(1) As found in previous trials, the application of potash to plant cane growing on the ratooning areas of the red soil districts invariably results in significant increases in yield.

(2) This deficiency of potash is not made good by dressings of pen manure at the rate of either 10, 20 or 30 tons per acre. Available potash such as is supplied by sulphate of potash is necessary.

(3) Heavy dressings of sulphate of ammonia to plant cane which had had no effect on the yield, presumably owing to a sufficiency of nitrogen in the soil, had no residual effect on the ratoons. The ratoons in question gave increased yields of 6 tons cane per acre, as a result of doubling the application of sulphate of ammonia actually applied to the ratoons.

(4) Increasing doses of nitrogen as sulphate of ammonia had a depressing effect on the sucrose content of ratooned cane. This depressing effect could be partially or entirely offset by increased potash manuring.

(5) The comparison of different doses of pen manure on the yield of plant cane showed that, in a year with the rainfall above the average, 10 tons of pen manure gave as large a yield as 20 or 30 tons.

(6) A mixture of artificial manures supplying 100 lb. potash and 60 lb. nitrogen per acre, gave yields of plant cane which were as heavy or heavier than those obtained with dressings of 10, 20 and 30 tons pen manure.

(7) Dressings of 10, 20 or 30 tons of pen manure per acre to plant cane have little or no residual value on ratoon cane that has received 100 lb. potash per acre as sulphate of potash and 45 or 90 lb. nitrogen per acre as sulphate of ammonia. This result was obtained in spite of the fact that the difference between the yields of the ratoons which had received the two dressings of sulphate of ammonia amounted to about 6 tons cane per acre.

RATE OF EGG DEPOSITION OF DIATRAEA SACCHARALIS

AND

EXTENT OF LARVAL MORTALITY IN CANEFIELDS

AND

THEIR RELATION TO CONTROL OF DIATRAEA BY TRICHOGRAMMA MINUTUM.

BY

R. W. E. TUCKER, M.A., B.ED.

The determination of the rate, or extent, of egg deposition by *Diatraea saccharalis* in canefields, and the extent of larval mortality are problems beset with many difficulties. Neither egg deposition nor rate of larval mortality are constant factors, but vary with the time of the year, stage of cane growth, temperature and humidity, rainfall and probably with wind velocity and variety of cane.

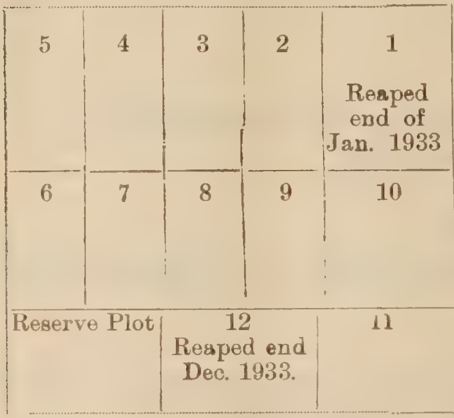
Entomologists with experience of field work on *D. saccharalis* in cane will know that in addition to this, the moths by no means oviposit in a uniform fashion; some stools or some areas of a field may have numerous egg clusters deposited on them and others may have none at all. There is nothing like uniformity of egg deposition, and to select 5 cane stools, as some workers have done and then multiply their findings on these stools up to 2,500 stools or even to take 25 stools, and multiply up to 3,500 stools per acre and claim the result as the rate of egg deposition per acre, can be very misleading.

Moreover, the facts as obtained by experiments carried out in Barbados to gather information on the question of rate of egg deposition and extent of larval mortality give very different results from those recently published elsewhere. These experiments which are on a large scale, and carefully controlled and scrutinised are as follows.

FIELD EXPERIMENTS ON EGG DEPOSITION AND LARVAL SURVIVAL.

To determine egg deposition and larval mortality, a block of B.726 canes was planted at Codrington Experiment Station in November, 1932, as shown

in the accompanying plan. This block was divided into 12 equal plots each of 40 stools, with a guard row of canes round the entire block, and a spare or reserve plot as shown. The experimental area was thus 480 cane holes, and as in this experiment there are 1,742 holes per acre, the entire area under observation was thus between one-third and one-fourth of an acre. The plots 1—12 were continuous and only marked by white stakes at the corners.



The entire block was separated from other canefields by other crops; though, as must perforce happen in Barbados, the furthest of these surrounding canefields was less than 400 yards away and the nearest about 50 yards, though when these were reaped the nearest field was over 100 yards to leeward. To ensure that the block should carry a good borer population on which to work it was deliberately infested in January and February by placing cut bored canes in simulation of an immediately adjacent infested field. When eggs were found in abundance this artificial infestation was discontinued. No parasites were liberated in these plots.

A worker was first trained to look for and to spot *Diatraea* egg masses, and then, at the end of the first week in January he was set to examine blade by blade, the young shoots in plots 1—12. When an egg mass was discovered, a spot of paint was put on the leaf near it, and a rod or small stake placed in the ground alongside to mark the stool. Following this searcher, came another who had previous training and experience in searching for *Diatraea* egg masses, and he checked up the results. Finally, the writer came along, and by means of a hand lens, counted each marked egg mass, recorded the number of clusters, egg parasitism, etc., for each plot; at the same time, a further search was made for clusters missed by the previous searchers. This search was made on Mondays and Fridays *each week* and at every search the paint colour, or the shape of the mark was altered so that no previous counts could be again included. Although it is not claimed that some egg masses did not escape this triple search, the error is probably as small as could be obtained in any such work, and the results are definite for an area large enough and for a period long enough to be worth considering. Moreover, a further check was obtained when each plot was reaped and again examined leaf by leaf as described later.

By these means, the number of eggs laid in each of the 12 plots constituting the area under examination was determined with reasonable accuracy, and the egg deposition plot by plot, and per acre, month by month, is given in Tables X and XI. The normal irregularity of egg deposition can be seen at a glance in Table X; stool by stool, the irregularity would be vastly greater. At the same time, the careful records made of eggs parasitised, and eggs destroyed by other agencies (described later, p. 49), enabled an accurate computation to be made of the number of larvae which actually hatched in each

individual plot each month. At the end of each month, one plot was reaped: thus Plot I was reaped at the end of January 1933; Plot 2 at the end of February and so on. Every shoot of the 40 cane stools thus reaped was brought to the laboratory and examined leaf by leaf and stem by stem. In this manner records were obtained of (a) attempts at larval survival (b) ultimate larval survival which were then correlated with the number of larvae known to have hatched in that plot. It is necessary to draw this distinction between early attempts at larval survival and final survival, because it might be imagined by some people who read records of early larval mortality that over 90% of the newly hatched larvae die or disappear immediately they hatch; this is obviously inferred by the statement that the natural early larval mortality renders valueless the killing of *Diatraea* eggs by *Trichogramma*. For the statement to have any meaning or value at all, it is necessary for the larvae to die naturally *immediately* they hatch, otherwise how can early larval mortality be classed with egg mortality. It is on the other hand only common sense to consider that once the larvae *have* hatched and moved away from the egg mass and started feeding, or searching for suitable vantage points of feeding or entry their mortality is entirely dissociated from, and unconnected with, egg mortality. This is proved by the fact that examination of these plots shows that large numbers of very young larvae *do* feed or attempt to enter the cane, and they survive long enough to leave numerous records such as leaf perforation, mid-rib borings, etc., as detailed in Tables I to IX. The fact that large numbers eventually fail to enter the cane and survive shows that either a limited number only are physically capable of survival or that mortality factors entirely independent of, and unconnected with, egg mortality such as rain, wind, temperature and varietal resistance as described later, will always be at work to reduce survivors however few or many larvae hatch.

The evaluation of various mortality factors such as destruction of *Diatraea* eggs by *Trichogramma* and other agencies, early larval mortality from the above causes, and late larval mortality due to larval parasites when present must always be made on a comparable basis such as real destruction of total initial population.

There are methods of expressing the real destruction due to various factors by means of formulae which take into account the various mortality factors in their sequence in the life cycle and the correct use of such methods enables the real value of *Trichogramma* to be determined. It is necessary however that other mortality factors should be expressed in the same terms, if it is desired to make comparisons, and that the apparent effect of any such factor should, in the first place, be correctly determined.

The real value of *Trichogramma* and the increase of such value by mass colonisations is as fully apparent from fair comparison as it is from actual results in the field.

EXAMINATION OF DATA.

The records obtained by these regular bi-weekly egg counts, and monthly reaping, examination and dissection of one plot of 40 cane stools, thus give re-

liable data concerning rate of egg deposition, larval attempts at survival and ultimate larval survival in areas large enough to warrant conclusions being drawn from them. It will be seen that the results differ month by month, as is to be expected. Records of larval attempts at survival show definitely that nothing like over 90% die immediately, and that quite a number bore into the stems before disappearing. In the month of July 34.5% of the larvae which actually hatched, succeeded in entering the cane and causing damage, leaving an ultimate mortality of 65.5% only, and in Plot 8 in August 100% of larvae recorded as hatching, survived and entered canes, larval mortality being 0%.

These monthly records are given in detail below. Two assumptions have of necessity been made, namely, that young larvae which drift away on air currents soon after hatching, are balanced by larvae drifting in; also, that larvae and unhatched pupae found in canes dissected are derived from larvae which hatched in that plot during the month under consideration. There is no means of checking the first assumption and the second assumption is not strictly accurate, because the period from newly hatched larva to pupa is sometimes more than 30 or 31 days; to try and ascertain, however, whether the pupae found in each monthly reaped plot had resulted from slow or quick developing larvae would be impossible. Moreover, the living pupae which are included as developing within a space of 30—31 days are much less in number than the empty pupal cases, which, though definite evidence of larval survival, cannot be dated with anything like certainty, and are therefore counted only in the general evidences of larval survival and not in the ultimate survival percentage. As often stated exactitude in this work is impossible, but the writer endeavours to use the minimum of records or observations which may have a wide margin of interpretation, and if used, attention is drawn to that possibility.

It must also be pointed out that as each plot was reaped, and the presence of and damage by larvae recorded, a record was made of the number of egg masses left unmarked during the bi-weekly searches. It was found to be impossible to make an exact monthly correction for errors thus arising, because in some months the reaping of the plot was not started till the 1st or 2nd of the next month and reaping in some cases occupied three days because the laboratory staff was not able at that particular time, owing to pressure of other work, to cope with the long process of detailed examination of each shoot and leaves. Obviously, it was no use reaping more canes per day than could be examined in one day, because cane leaves roll up very quickly when their moisture supply is cut off and in consequence are hard to examine, particularly for *Diatraea* egg masses. Owing to delays in reaping some plots, unmarked egg clusters, representing four, or even five nights egg deposition since the last time of searching and marking, were bound to occur. This is from May onwards; up to April it was usually possible to examine an entire plot blade by blade in one or two days. As distinction was not made, in cases where the reaping period was prolonged as stated, of egg masses which had clearly been deposited since the last search, it was impossible to determine exactly the error due to missed egg masses, for each month.

Nevertheless, frequent bi-weekly checks of uncounted egg masses were made, and from these, and independent checks of and by other trained field workers on the subject of missing egg masses in field counts, it can be stated that the error in any of these counts never exceeds 20%, and is often as low as 2%. A

general average of 15% error more than covers the eggs missed month by month, and if this correction is applied to the figures given in Table XI for egg deposition per acre, a full and generous allowance will have been made.

Moreover, when considering the records of larval survival as evidenced by their presence, or by their feeding marks or borings, it must be remembered that leaves which were perforated or otherwise fed on by young larvae in February, March and part of April, have largely died down and fallen off as trash from the older shoots during the dry months of March, April, May and part of June. There are therefore no records of the survival of larvae from eggs recorded as hatching in these months, to be found in plots reaped from June onwards. Moreover, much larval damage to young stems where larvae have effected only partial penetration before disappearing, will be lost sight of later on in mature canes which have outgrown such shallow surface penetration: also small early formed dead hearts tend to rot or drop off from maturing stools and are also lost sight of from say August onwards.

The records given below of larval survival therefore cannot possibly err on the side of exaggeration; from the very nature of the task, as well as from the above causes, larval survival figures are likely to be under their true figure. The writer fully realises the difficulties and pitfalls of these investigations and attempts to state no conclusions beyond those really warranted by the facts. The facts have been obtained by well organised, supervised, and checked examinations to determine on as large a scale as can safely be handled, the objects stated in the heading of this paper.

With these forewords as to the nature and operation of the experiments, the results are given below. It is necessary to state again that these plots were *not* colonised with *Trichogramma*: any parasitism resulted from parasites drifting in from neighbouring fields, some of which were colonised as part of plantation routine.

TABLE I.

Plot 1. Reaped January 31st. .. .. .. 40 stools. 121 shoots.

Larval perforations of leaves and of central leaf spike	11		
Stem borings	1	Total	15.
Living larvae	3		
Number of eggs laid in January in 12 plots —	1319 or 4,744 per acre.		
,, ,, ,, actually hatched in 12 plots —	1115 = 84.4%		
,, ,, ,, parasitised by *Trichogramma* —	11 = 0.83%		
,, ,, ,, killed by predators, etc. (see p. 49)	193 = 14.6%		
Eggs laid in Plot I. only in January	108		
Eggs parasitised in Plot I. .. .. .. —	0		
Eggs killed by predators, etc., in Plot I ..	0		
Eggs unhatched on reaping .. .. .. —	33		
Total actually hatching in Plot I. .. .. —	75		

NOTE:—If a living larva is found and recorded, no duplicate record of stem or leaf spike bored is made; similarly, if a pupal case is found in a dead heart only the pupal case is recorded. This holds good throughout.

No eggs were laid in Plot I. before January 27th. Of the 3 living larvae found when the plot was reaped 5 days later, 2 only were small enough to have resulted from these eggs; the remaining larva was at least 10 days old. As there were no eggs in this plot which could have given rise to it, it must have wind-drifted or migrated in. Moreover, the 12 larval feeding records are obviously due to extraneous larvae because their work was weeks older than any eggs laid in Plot I. This is supported by the fact that early in February it was observed that Plots 11 and 12 had each a stool showing a dead heart. Neither of these stools when searched most carefully had any egg masses laid on them, nor had any been recorded on them throughout January. The larvae causing the dead hearts had therefore come from other sources as stated above.

In Plot I therefore two larvae survived on the spot out of 75 which hatched. This makes larval survival for January 2.66% and mortality 97.34%.

TABLE II.

Plot II. Reaped February 28th. 40 holes. 281 shoots.

Larval perforations of leaves	17	
Midrib borings	5	Total 34.
Stem borings	3	
Living larvae	9	

Number of eggs deposited in February in 11 plots = 3,566 = 14,118 per acre.
,, ,, ,, actually hatched ,, ,, ,, = 2,911 = 81.6%
,, ,, ,, parasitised by *Trichogramma* ,, ,, ,, = 285 = 8.0%
,, ,, ,, otherwise killed ,, ,, ,, = 319 = 8.7%

Eggs laid in Plot 2 in February	= 618
,, parasitised in Plot 2 in Feby.	= 44 =7.1%
,, killed by predators	= 120 =19.4%
,, unhatched on reaping	= 51
,, actually hatching, therefore	= 403 of which 9 survive as larvae =2.2% survived

Ultimate mortality therefore 97.8%. Also in Plot II 83 larvae hatched from eggs laid in January making 403 plus 83, or 486 larvae hatching and leaving 34 records as above i.e., 7% early survival, which leaves 93% only larval mortality.

TABLE III.

Plot III. Reaped March 30th. 40 holes. 532 shoots.

Larval perforations of leaves	76	Stem borings	20
Midrib borings	8	Dead hearts	7
Rolled spike perforations ..	4	Larvae	36
		Pupae {Unhatched	1
		{Hatched	0

Total 115 larval traces
37 survivals

Number of eggs deposited in March in 10 plots = 5,516 = 24,022 per acre.
" " " actually hatched in March in 10 plots = 3,402 = 61.6%
" " " parasitised by *Trichogramma* in March in 10 plots = 338 = 6.1%
" " " otherwise killed in March in 10 plots = 1,776 = 32.2%
Eggs laid in Plot 3 in March = 776
" parasitised " " " = 22 = 2.83%
" otherwise killed in " = 259 = 33.38%

Eggs actually hatching therefore in Plot 3 in March = 495 of which 37 survivals as shown above = 7.41% larval survival.

Ultimate mortality therefore is 92.59%.

Counting from commencement of egg deposition, records show 826 larvae hatching in this Plot, and as shown above, 152 total records of larval presence, which gives an initial mortality of 81.71%.

TABLE IV.

Plot 4. Reaped April 28 and 29 and May 1st. 39 holes, 513 shoots.

Leaf perforations	55	Dead hearts ..	12	
Midrib borings	24	Living larvae ..	42	Total larval
Basal sheath feeding	24	Pupae (Empty)	5	records - 180
		(Full)	0	
Stems bored	18			

Eggs deposited in Plots 4—12 in April = 4,155 or 20,105 per acre.
" parasitised " " " " " " = 480 " 11.55%
" otherwise killed " " " " " = 1,415 " 34.05%
" actually hatching " " " " = 2,260 " 54.40%
" deposited in Plot 4 only in April = 749
" parasitised " " " " " = 25 or 3.3%
" otherwise killed " " " " " = 368 " 49.0%
" actually hatching " " " " = 356 " 47.5%
Total of eggs deposited in Plot 4 Jan. — Apr. = 1,497
" " " hatching " " " " " = 875

Thus in Plot 4, 356 larvae hatched in April, and at the end of April 42 living larvae were recovered from this Plot, which is 11.8% larval survival, and 88.2% ultimate mortality. Further in Plot 4, a total of 875 larvae hatched during its period of growth, and these left a total of 180 larval records as above, showing 20.57% initial survival, and 79.43% early larval mortality.

TABLE V.

Plot 5. Reaped May 31st and June 1st. 40 holes 606 shoots.

Leaf perforations	58	Dead hearts ..	41	
Midrib borings	34	Living larvae ..	22	
Basal sheath feeding	154	Pupae {Full ..	0	Total larval
		{Empty	3	records — 396
Stems bored	77	Central Shoot perforations ..	7	

Eggs deposited in Plots 5—12 in May	= 3,693 or 20,358 per acre.
,, parasitised ,, ,, ,, ,, ,,	= 1,179 ,, 31.92%
,, otherwise killed ,, ,, ,, ,, ,,	= 879 ,, 23.8%
,, actually hatching ,, ,, ,, ,, ,,	= 1,635 = 44.27%
,, deposited in Plot 5 only in May	= 637
,, parasitised ,, ,, ,, ,, ,, ,,	= 173 or 27.1%
,, otherwise killed ,, ,, ,, ,, ,,	= 154 ,, 24.1%
,, actually hatching ,, ,, ,, ,,	= 310 ,, 48.7%
Total of eggs deposited in Plot 5 in Jan.—May	= 1,583
,, ,, ,, hatching ,, ,, ,, ,, ,, ,,	= 1,270

Thus in Plot 5 in May 310 larvae hatched out, and 22 living larvae were in the canes when reaped, which is 7.1% larval survival, or 92.9% ultimate mortality. Further in Plot 5, 1,270 larvae hatched out during total growing period, and 396 larval records were recovered, showing an initial survival of 31.19%, or 68.81% early larval mortality.

TABLE VI.

Plot 6. Reaped July 1—3. 39 holes. 574 shoots.

Leaf perforations ..	63	Dead hearts	101	
Midrib borings ..	41	Central shoot ..		
Basil sheath tunnels	270	perforations ..	3	Total 692.
		Living larvae ..	14	
Stems bored	191	Pupae (Full) ..	3	
		(Empty) ..	6	

Eggs deposited in Plots 6—12 in June	= 1,186 or 7,485 per acre.
,, parasitised ,, ,, ,, ,, ,,	= 391 ,, 32.88%
,, otherwise killed ,, ,, ,, ,, ,,	= 262 ,, 22.08%
,, actually hatching ,, ,, ,, ,,	= 533 ,, 45.0%
,, deposited in Plot 6 only in June	= 335
,, parasitised ,, ,, ,, ,, ,,	= 44 or 13.1%
,, otherwise killed ,, ,, ,, ,, ,,	= 129 ,, 38.5%
,, actually hatching ,, ,, ,, ,,	= 162 ,, 48.3%
Total of eggs deposited in Plot 6 in Jan–June	= 2,312
,, ,, ,, hatching ,, ,, ,, ,, ,, ,,	= 1,488

Thus in Plot 6 in June 162 larvae hatched out and 17 larvae and unhatched pupae were found when this Plot was reaped, which is 10.5% larval survival or 89.5% ultimate mortality. Further in Plot 6, 1,650 larvae hatched from January to June, and 692 larval records were obtained which is 41.94% initial survival of larvae, and 58.06% early larval mortality. Moreover, this figure of early larval mortality is probably *too high* because by June, leaves damaged in February and part of March are beginning to dry up and drop off, and therefore the figure 692 above is too low.

At this point, attention may be drawn to a quite unplanned check upon the intensity of borer infestation in the foregoing experimental plots. It is interesting to know how these plots compare with the general average of fields on plantations all over the island. As it happens, every year, field counts are made in as many areas as possible, of the number of dead hearts in 100 random selected stools in random selected fields. This was done as usual in 1933 with no idea of comparison with the experimental plots. Naturally, as the field counts are made in widely different localities, on different varieties, and from a much larger number of stools, one would expect some difference from the counts of dead hearts in the experimental plots. The actual figures, however, for the three months in which field counts are made, are:—

	Experimental Plots	Field Counts.
March	1.31% dead hearts in 532 shoots	1.88% in 13,800 shoots
April	2.34% dead hearts in 513 ,,	2.27% in 14,350 ,,
May	6.76% dead hearts in 606 ,,	3.87% in 5,785 ,,

The evidence therefore is in favour of the experimental plots being slightly more heavily infested than the average plantation field, so that the numbers of eggs per acre given in Table XI are not specially culled from a slightly infested area, but are typical of fair average conditions, with a probability of just above average borer infestation, due possibly to the deliberate initial infestation given, or to reduced infestation in fields due to systematic parasite liberations.

TABLE VII.

Plot 7. Reaped 1st-3rd August. 38 stools: 507 shoots.

Leaf perforations	36	Dead hearts ..	38	
Midrib borings	27	Central spike		
Basal sheath feeding	34	perforations ..	7	
		Living larvae ..	20	Total 335.
Stems bored	162*	Pupae {Hatched	9	
		{Full ..	2	

Eggs deposited in Plots 7—12 in July = 288 or 2,108 per acre.
,, parasitised ,, ,, ,, ,, ,, ,, = 54 or 18.75%
,, otherwise killed ,, ,, ,, ,, ,, = 84 or 29.16%
,, hatching ,, ,, ,, ,, ,, = 150 or 52.08%
,, deposited in Plot 7 in July = 111
,, parasitised ,, ,, ,, ,, ,, = 23 or 20.72%
,, otherwise killed ,, ,, ,, ,, = 24 ,, 21.62%
,, actually hatching ,, ,, ,, = 64 ,, 57.65%
Total of eggs deposited in Plot 7 in Jan.—July = 2,761
,, ,, ,, hatching ,, ,, ,, ,, ,, = 1,631

Thus in Plot 7, 64 larvae hatched in July, and 22 living larvae were recovered from the plot at the end of the month, which is 34.5% actual survival, or 65.5% ultimate mortality. Further in Plot 7, a total of 1,631 larvae hatched during the total period of growth, and these left records as given above of 335 early survivals, which is 20.55% initial larval survival, and 79.45% early mortality.

As in Table VI, the initial survival figures are too low, because in April, May and most of June, prolonged dry weather causes drying and falling of cane leaves, thus obliterating records of early larval survival made in February, March and probably part of April.

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*This does not mean 162 separate stems bored, as some stems often have 2 or 3 separate larval borings.

TABLE VIII.

Plot 8. Reaped Sept. 1—5. 38 stools. 499 shoots.

Leaf perforations	15	Dead hearts ..	32	
Midrib borings	9	Central spike perforation ..	1	..Total 399
Basal sheath feeding	43	Living larvae ..	30	
Stems bored	252*	Pupae { Full ..	2	
		Hatched	15	

Eggs deposited in Plots 8—12 in August = 271 or 2,408 per acre.
„ parasitised „ „ „ „ „ „ = 89 „ 32.84%
„ otherwise killed „ „ „ „ „ = 109 „ 40.22%
„ actually hatching „ „ „ „ = 73 „ 26.94%
„ deposited in Plot 8 in August = 53
„ parasitised „ „ „ „ „ = 40 or 75.4%
„ otherwise killed „ „ „ „ = 0
„ actually hatching „ „ „ = 13 or 24.5%
Total of eggs deposited in Plot 8 in Jan.—August = 1,953
„ „ „ hatched „ „ „ „ „ „ = 1,160

Thus in Plot 4, 13 eggs produced larvae, and, when reaped, the plot contained 30 living larvae (of which 15 were small) and 2 unhatched pupae. Hence not only would it appear that 100% of larvae hatching survived in this plot in August, but that 17 larvae came in from other sources, either by air current deposition or by migration from stools in the other plots. These figures are given as obtained and recorded, and though it is quite possible that this is an extreme case of larval survival, namely 100%, plus larvae from external sources, the facts are as recorded, and clearly indicate a very high larval survival, and correspondingly a very low larval mortality at this time of year.

With regard to total eggs hatching in this plot, and total larval records, it is so obvious that larval records made in January and February have been lost that larval hatchings from April to August only are considered. The figure of actual larval hatchings for April August in Plot 8 is 617. The larval records on the leaves and stems examined were 399 which is 64.6% initial larval survival in August and 35.4% early larval mortality.

*Many stems have 2 or 3 separate larval borings.

TABLE IX.

Plot 9. Reaped October 3rd and 4th. 40 stools. 427 shoots.

Leaf perforations	14	Dead hearts ..	17	
Midrib borings ..	3	Central shoot		
Basal sheath tunnels	32	perforations	0	Total 359
		Living larvae ..	41	
Stem borings ..	236	Pupae {Full ..	2	
		{Hatched	14	

Eggs deposited in Plots 9—12 in September	=	465 or 5,192 per acre.
,, parasitised ,, ,, ,, ,, ,, ,,	=	242 or 52.04%
,, otherwise killed ,, ,, ,, ,, ,,	=	20 or 4.30%
,, actually hatching ,, ,, ,, ,,	=	179 or 43.66%
,, deposited in Plot 9 only in September	=	140
,, parasitised ,, ,, ,, ,, ,,	=	89 or 63.6%
,, otherwise killed ,, ,, ,, ,,	=	0
,, actually hatching ,, ,, ,, ,,	=	51 or 36.4%
Total eggs deposited in Plot 9 in April—Sept.	=	1,170
,, ,, actually hatching	=	521

Thus in Plot 9 in September 51 larvae hatched and 43 larvae and unhatched pupae were recovered when the plot was reaped which is 84.3% larval survival or 15.7% ultimate mortality. Further in Plot 9, 521 larvae hatched from April to September and left 359 records as above, which is 68.9% initial survival and 31.1% early larval mortality.

TABLE X.

RECORD OF MONTHLY DEPOSITION OF DIATRAEA EGGS IN TWELVE EXPERIMENTAL PLOTS.

Plot.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
1	108	—	—	—	—	—	—	—	—
2	118	618	—	—	—	—	—	—	—
3	66	316	776	—	—	—	—	—	—
4	24	228	496	749	—	—	—	—	—
5	96	380	667	440	637	—	—	—	—
6	198	190	737	624	563	335	—	—	—
7	182	243	497	554	797	377	111	—	—
8	165	288	319	392	551	167	71	53	—
9	124	333	536	626	247	108	9	40	140
10	0	309	345	250	418	57	55	41	182
11	89	139	330	233	201	83	25	45	90
12	149	522	813	287	289	59	17	84	53
	1,319	3,566	5,516	4,155	3,693	1,186	288	271	465

Reading vertically gives the variations in eggs laid in the different plots of the one third acre block in each month (a space record as it were) and reading horizontally gives the variations in each individual plot month by month (a time record).

The vertical readings record the monthly variations in *total* eggs per month in each plot (the bi-weekly records are often far more extreme in their variation) and show clearly the natural irregularity of egg deposition in the various portions of this one-third acre plot.

As repeatedly stated, this natural irregularity of egg deposition by *Diatraea* is a factor which must always be taken into account and which will vitiate anything but numerous observations, in as many areas as possible, on as large a scale as possible, and over long periods of time. Conclusions drawn from a few stools of cane only are useless.

The horizontal readings show the seasonal deposition and in the majority of cases show a definite and normal rise in the curve of egg deposition to a maximum in April-May, and a steady diminution from June onwards.

From the final row of summation figures the deposition per acre is obtained as in Table XI.

TABLE XI.

SUMMARY OF DATA IN TABLES I TO X.

Plot.	Reaped.	Cane holes examined (1 plot less each month,)	No. of eggs deposited *per acre*.	Para. sitism of eggs by *Trichogramma* (not colonised.)	Eggs killed by mites and Psocids.	Early mortality of larvae in each plot to period of reaping.	Percentage larvae found alive each month out of actual hatch of larvae.	Ultimate mortality of larvae each month.
				%	%	%	%	%
1	Jan.	480	4,744	0.83	14.60	97.34	2.66	97.34
2	Feb.	440	14,118	8.00	8.70	93.00	2.20	97.80
3	March	400	24,022	6.10	32.20	81.71	7.41	92.59
4	April	360	20,105	11.55	34.05	79.43	11.80	88.20
5	May	318	20,358	31.92	23.80	68.81	7.10	92.90
6	June	276	7,485	32.88	22.08	58.06	10.50	89.50
7	July	234	2,108	18.75	29.16	79.45	34.50	65.50
8	Aug.	196	2,408	32.84	40.22	35.40	100.0	0.0
9	Sept.	156	5,192	52.04	4.30	31.10	24.3	15.7

In these uncolonised plots, it is also evident that egg mortality due to Bdellid mites and Psocid larvae (p. 49) is a very important factor. This egg mortality has not been noticed or recorded before, and, in view of the fact that egg masses which have been sucked dry, or torn open and the contents eaten, can easily be mistaken for hatched egg masses, it is obvious that the number of *Diatraea* larvae which actually hatch is not so large as some workers imagine.

It is also obvious that neither early, nor ultimate larval mortality is as high as some writers would have them. As stated in (2) it is probable that during *some* months of the year, early larval mortality is correctly stated to be over 90 per cent. of the total hatch. In other months, when the canes are far more susceptible to penetration and damage, and when damaged growth cannot be

replaced by new shoots but remains damaged till reaping time, observations in Barbados show that conditions are more favourable to larval survival, and larval mortality is nothing like as high as the figures which are so misleadingly given elsewhere as, presumably, for every month and all conditions. Naturally, with a higher rate of larval survival, the importance of and effectiveness of killing eggs by *Trichogramma* is greatly enhanced. It is not entirely correct, therefore to say that "over 90 per cent.* of the young larvae which are killed in the egg by "the egg parasites, would have died in any case" and that this therefore renders almost ineffective any increase in egg parasitism brought about by mass rearing and colonising *Trichogramma.*

The fact remains that independent workers in Barbados, Louisiana and Peru have, over a series of years of work, consistently found that mass reared and properly colonised *Trichogramma* are effective in reducing infestation of *D. saccharalis* in cane.

It is also obvious from a comparison of the figures of eggs per acre per month now found in Barbados, with those of from ten to fifteen times the amount for an unspecified time found elsewhere that either the error in the latter case, due to so few stools being selected, is out of all proportion, or, that moth borer in Barbados is definitely coming under control, and that the yearly diminution in infestation found by large scale examination of each crop, is truly based on facts.

It would also be imagined from statements published on this question that *D. saccharalis* is unique amongst insect pests in suffering from extensive early larval mortality at certain periods, instead of such conditions being common, particularly to pests of normal fecundity. Very few major pests in fact are so intimately associated with large and continuous supplies of their food plants as is *D. saccharalis* and therefore one would imagine far less liable to suffer unnatural larval mortality.

Yet, with other pests doubtless with similar or even greater larval mortality, egg parasites and predators have proved effective as controlling agents; and *Trichogramma,* when manipulated so as to increase its natural range and effectiveness, is no exception.

Experiments on a small scale, based on the natural occurrence of *Trichogramma* prove only what is already well known, namely, that *Trichogramma* does not fully control *Diatraea* in its natural state though it most probably prevents cane growing from becoming impossible in some areas.

INDEPENDENT DETERMINATION OF DIATRAEA EGGS PER ACRE.

As a check upon figures of *Diatraea* eggs per acre obtained in the foregoing continuous experiment, it was arranged to search thoroughly an area of about

*In a more recent publication (Sept. 1933), Mr. H. E. Box raises the figure to an average of 97% of young *Diatraea* larvae which perish before they have committed any damage.

one-third of an acre in four different fields. The fields were chosen from the farm of the Government Reformatory School for Boys, where intelligent and disciplined labour could be obtained, and where preliminary training could be given in the work of examining canes stool by stool in the field, and in finding and collecting the egg masses of *D. saccharalis*. The experiment was then conducted as follows. Eight trained boys were each given a row of 80 stools to examine, which, at the stage of cane growth in June, was considered well within their training and capability. The total area examined was thus about one-third of an acre. The stools were examined shoot by shoot and leaf by leaf, under supervision, and all egg masses removed on a portion of leaf and placed in a tin carried by each boy. Behind this line of workers followed overseers and behind them again Departmental officers, who searched the cane stools for egg masses which had escaped the previous line of searchers. When each 80 stools had been searched, the boys were changed around, and made to search rows other than their own. This work, though tedious, was done and supervised well, and it is reasonable to consider that the error due to egg masses which escaped this scrutiny was considerably less than the average 15 per cent. error. The fields in which the searches were made were in every way well grown and normal fields, and the period of the year, June, was such that moth borer egg deposition should have been plentiful and approaching maximum infestation. The results obtained, of eggs per acre, in these four fields are therefore reasonably indicative of the rate of egg deposition per acre at this period. Taking an average of these four separate areas, which together amount to over 1⅓ acres, the egg deposition per acre amounts to 6,576, which is reasonably close to the June figure given in Table XI. The per cent. parasitism, namely a real (not average) parasitism of 70% shows clearly the difference in the figure for June between colonised fields, as these were, and the June figure for an uncolonised field, Table XI. Also, the eggs per acre in the comparable B.726 fields are less in the colonised field than in the uncolonised experimental block, which is in accordance with practical experience and observations that properly colonised *Trichogramma* reduces infestation. In the case of B.726 records were also made of egg clusters killed by mites and Psocids, as recorded in the Codrington experiment. The results showed 431 eggs so killed, i.e., 18.28%, which is within reasonable agreement with the 22.08% recorded for the entire month of June at Codrington.

TABLE XII.

Field.	Variety.	No. of holes.	Date.	No. of eggs.	Eggs per acre.	Per cent. parasitism.
Lower Bay Tree	B. 726	621	9/6/33	2,357	6,612	49.4 %
,, ,, ,,	Ba. 11569	545	10/6/33	3,708	11,852	83.2 %
Walls Field	B. 2935	625	14/6/33	1,301	3,386	87.5 %
Upper Bay Tree	B. 891	623	15/6/33	1,539	4,454	70.0 %

In connection with field determination of parasitism by *Trichogramma* by removing and collecting egg masses on portions of leaves, one writer has published the statement that he objects to this method because of the human error, and because parasitised egg masses, being black, show up more readily than white unparasitised or empty egg masses. The latter objection may be true for untrained workers or inexperienced observers searching for egg masses for the first time; but it is most certainly not true for anyone of experience or intelligence. *Diatraea* egg masses are so openly exposed on the broad cane leaves, that whether they are black, white or brownish pink (partly developed) or laid on cane blade or midrib, they are seldom missed by conscientious searchers.

The foregoing records and tables show clearly that from twelve separate determinations on an adequate scale of the rate of egg deposition per acre by *Diatraea saccharalis* in cane, the highest egg deposition recorded is 24,000 per acre per month; adding the 15% correction which was the average established error for eggs missed in the controlled bi-weekly searches, one gets a *maximum* total of 27,600 eggs per acre. Moreover, there is an obvious diminution in egg laying from June onwards, although in years prior to early, systematic, large scale *Trichogramma* colonisation, these were the months in which *Diatraea* egg deposition normally increased and reached its maximum. It is also apparent that natural parasitism, as always stated, is invariably low during the early months of the year, though in this case, parasites are bound to have drifted in from neighbouring colonised fields, so that from May onwards one sees an increase in percentage parasitism, despite a falling host population. Where fields are deliberately and consistently colonised, this increase in parasitism naturally reaches much higher figures (Table XII). Moreover, whilst on the subject of parasitism by *Trichogramma*, counts of parasites hatching from a series of *Diatraea* egg masses collected in the field in Barbados show that an average of 1.78 *Trichogramma* emerge per *Diatraea* egg which in round figures can be called 1¾ parasites per egg in contrast with the 2½ parasites per egg as quoted for Antigua in (1).

The difference between 1¾ and 2½ parasites per egg means a difference of approximatly 43% in the figures of parasites per acre, reported to be of daily occurrence in Antigua.

This 43% increase, coupled with 10 to 15 times the number of eggs per acre also recorded in (1), compared with those found by careful large scale work in Barbados, shows that either figures are at fault, or that there is no comparison between moth borer conditions in Antigua and Barbados.

Criticisms based on such figures, and for natural occurrences of *Trichogramma* and *Diatraea* in Antigua have therefore no bearing on or relation to, the conditions which are being created, and the results which have been obtained in Barbados from the systematic mass colonisation of *Trichogramma*.

PREDATORS OF EGGS OF D. SACCHARALIS.

In Tables I to IX it will be noticed that constant reference is made to eggs killed by causes other than parasitism by *Trichogramma*.

In the course of the bi-weekly examination and counts of eggs in the egg deposition plots, it was noticed towards the end of January that not only had a large number of unparasitised egg clusters hatched out in the absolute minimum, or *under* the minimum period of egg development, which elapsed from one examination to another but that many egg clusters which could only have been laid and hatched since the previous examination had the appearance of "old" or weather beaten empty masess. Finally, when *partially* damaged clusters were found, or when parasitised eggs were found which were obviously torn open and eaten, care was taken when making counts not to touch or disturb stools marked as containing egg clusters, and to spot the egg cluster from its adjacent paint mark and examine it without handling the leaf. In this way, it was found that Bdellid mites, Fam. *Erythraeidae* Gen. *Atomus** were frequently on the clusters, busily sucking out the contents of each egg, leaving only the white shell behind. These insects were frequently found and several were captured. On two occasions Psocid larvae were seen at work on egg clusters, but could never be captured; these take alarm far more readily and disappear so rapidly that only twice were they actually caught at work; nevertheless, in the absence of any other agent capable of causing similar damage to the eggs, it is presumed that they were responsible for all this type of damage found. On two occasions ants have been found tugging and tearing at a partially damaged egg mass, but although ants are usually plentiful in canefields, the writer has only these two records of ants interfering with an egg cluster.

The sucking of eggs by the red *Erythraeid* mites, and the devouring of eggs by a predator, which from present evidence, appears to be the larval stage of a Psocid is however definite. In many cases, partially destroyed egg masses in all stages of development are found, and in some cases, the entire egg mass has been eaten away leaving only the silvery "scar," or, in the case of a parasitised egg mass, a dull grey or black edged outline of each egg of the mass.

The maximum period which elapsed between the bi-weekly examination of egg masses was four complete periods of 24 hours, with four nights during which eggs could be laid. But eggs laid on Monday night, after Monday morning's search and marking of all clusters, would be examined on Friday morning., i.e. three full periods of 24 hours, and a maximum of 12-14 more hours, supposing some clusters to have been laid as soon as darkness fell on Monday night. It is possible for *Diatraea* eggs to hatch in this minimum period, but such clusters would be so newly hatched that they could not be mistaken for anything else, and could not have acquired a dulled, or torn and generally weather beaten appearance; moreover, not many clusters would be laid just at that period, or would find conditions favourable for minimum period of development and hatching.

Once the new source of egg mortality had been traced, it was easy to determine whether an empty egg mass had hatched normally, or had been sucked or torn and eaten; normally hatched egg masses are clean, and each egg has a small arc-like opening through which the larva has emerged. Prior to this systematic bi-weekly examination of egg clusters, and the discovery of the predators mentioned, all empty egg masses found in field collections were considered as having

* Kindly determined by the Imperial Institute of Entomology from specimens sent.

hatched normally and if roughened or dulled in appearance, were considered as being old, long deposited masses. Hence till now, it has always been considered and stated by the writer (2) that unless parasitised, all *Diatraea* egg masses hatch and produce larvae.

Records given in Tables I to IX show that this predator mortality of eggs continues well into the period of maximum cane growth, though the proportion of eggs killed by *Atomus* decreases, and that due to Psocid larvae increases. This, however, would be expected owing to the fact that *Erythraeidae* are mainly soil inhabiting mites, and therefore eggs laid on tall dense cane growth would be less easy for them to find, whereas the Psocids apparently live on the cane plants, particularly in old, partly dried or trashed leaves.

This egg mortality overlaps parasitism due to *Trichogramma* since both *Atomus* and Psocid larvae will attack nearly mature egg masses and parasitised masses as well as newly laid ones. *Atomus*, however, definitely prefers newly laid masses and most of the destruction of parasitised eggs is due to Psocid larvae.

The question of the overlapping of parasites or predators of pest eggs has been well investigated in Hawaii and it is known that the sum total of egg destruction is more effective than that of any agent working separately, and that any agent which will increase this sum total of egg destruction is worth introducing or fostering.

No doubt the intrinsic efficacy of *Trichogramma* is in some cases diminished owing to egg masses being rendered unsuitable for parasitism by *Atomus*, or from parasitised masses being destroyed by Psocid larvae. This, however, does not alter the fact that increasing the efficiency of *Trichogramma* by properly organised, large scale colonisation of *Trichogramma* is bound to increase egg mortality of *Diatraea* and to decrease the number of larvae which hatch and ultimately survive to bore into and damage cane growth.

SUMMARY.

1. As the result of large scale and carefully supervised experiments it has been demonstrated that at present in Barbados, egg deposition by *Diatraea* has a maximum of 27,000 to 28,000 per acre and a minimum of around 2,500 per acre which is including a 15% correction for field errors; and that contrary to usual experience and expectation prior to effective *Trichogramma* colonisations this egg deposition diminishes from March onwards. The conditions under which the figures quoted in Tables I to XII were obtained, were fair average ones, and checks applied in random selected fields in the island month by month confirmed the findings.

2. During several months of the year, considerable *Diatraea* egg mortality is caused by the *Erythacid* mite *Atomus* sp. which punctures and sucks the eggs, and by a Psocid larva which eats out the egg contents, both working independently of and irrespective of parasitism by *Trichogramma*. The resultant egg masses can very easily be mistaken for "old" normally hatched masses. In the early part of the year egg mortality from these causes exceeds mortality due to natural parasitism

by *Trichogramma.* Later on, normal egg parasitism equals or surpasses and in colonised fields greatly exceeds, this mortality. The combined effect however is very greatly to lessen the number of young *Diatraea* larvae which are supposed by some writers to hatch out, which plus greater larval survival at critical periods of cane growth, renders effective the increased egg mortality due to organised mass colonisation of *Trichogramma.*

3. It is shown that early larval mortality does occasionally reach the figure of over 90 per cent., but only during the early months of the year, when cane growth is sparse. When the cane stools are well developed, and cane fields present a uniform slightly interlocking growth of 3 to 5 feet in height, larval mortality is less, and the survival rate and penetration of cane is much higher even up to 100 per cent. larval survival, and a corresponding 0 per cent. larval mortality. It is misleading to quote a 90 per cent.* mortality as presumably operative throughout the entire cane growing season.

4. The error of over-estimating the numbers of *Diatraea* eggs per acre, and of larvae which eventually hatch therefrom, and in presuming a continuous high larval mortality, and in considering that that presumed mortality renders largely ineffective the critically timed increase in egg destruction by the mass reared parasite *Trichogramma*, and in presuming extraordinarily large numbers of natural *Trichogramma* per acre is responsible for much misleading criticism of the effectiveness of *Trichogramma.* This parasite, correctly used, has been proved to be effective against *Diatraea* in cane in Barbados, Louisiana and Peru.

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*In a more recent publication (Sept. 1933), Mr. H. E. Box raises the figure to an average of 97% of young *Diatraea* larvae which perish before they have committed any damage.

VARIETAL FACTORS IN CANE WHICH MAY INFLUENCE EXTENT OF OVIPOSITION BY D. SACCHARALIS

AND

A POSSIBLE METHOD FOR DETERMINING VARIETAL SUSCEPTIBILITY TO BORER ATTACK

BY

R. W. E. TUCKER, M.A., B.Ed.

There would appear to be three factors inherent in cane varieties which are likely to affect the extent of egg deposition by *Diatraea* and the rate of larval survival and therefore of borer attack. They are:—(1) Chemo-tropism of the cane plant, (2) Oviposition stimulus of the cane leaf, (3) Ease of larval feeding and penetration and therefore of survival.

It is evident that as *D. saccharalis* oviposits only on canes, maize and some grasses, there is most probably a definite chemo-tropism due to the odour of this group of plants, which attracts borer moths; if this attraction is stronger on the part of any one variety of cane, it is reasonable to expect that more moths will fly to fields of that variety for oviposition.

When oviposition begins, it is also possible that the smoothness or roughness of the cane blade may influence the number of egg masses deposited, and the number of eggs per mass.

Both these factors are likely to affect the average number of eggs laid in any one variety.

Finally, when the larvae hatch out, and seek to feed and to penetrate the cane, much depends on the resistance offered by the plants to this feeding.

That different varieties of cane show different susceptibilities to borer attack is a well established fact, but the reasons for these differences are still not well known, though it is submitted that the three factors just mentioned will prove to be principal causes. If the causes of varietal susceptibility were definitely known, it is possible that they might be used in cane breeding experiments so that varieties could be bred which would automatically limit the prevalence of and damage due to *D. saccharalis*.

The question of chemo-tropism of different varieties of cane does not appear likely to be easily determined, except by very elaborate and extensive laboratory experiments. It would certainly not be possible to determine the actual adult moth population of any varietal cane area even for short periods. It would be

possible to make an extensive series of experiments to determine the average number of egg masses and of eggs laid week by week in a series of comparable varietal areas, or randomised varietal blocks, and, assuming that in this manner temperature, humidity, and climatic influences on oviposition were eliminated, any significant differences in numbers of eggs per variety might be attributed to the presence of greater numbers of ovipositing moths in that variety*

On the other hand, the second factor noted, namely the oviposition stimulus of the cane leaf surface has to be considered. It was first suggested to the writer by Mr. F. A. Stockdale, C.M.G., C.B.E., Agricultural Adviser to the Colonial Office, that the extent of hairiness, or shape and arrangement of hairs on cane leaves might influence oviposition by, and therefore infestation by, *Diatraea*, so that resistance to borer attack might be bred into canes by selection of varieties with oviposition inhibiting leaf surfaces. It is quite reasonable and possible that the roughness or smoothness or depth and frequency of striation on a cane leaf may stimulate or retard oviposition, and might therefore enhance or neutralise the chemo-tropism of that variety, and so prove to be a definite factor in determining varietal infestation.

An examination of cane blades however by tactile perception or by microscope does not show any outstanding differences, though one can say that B.726 is definitely smoother than P.O.J.2878 for example; but between canes of a class, such as the standard Barbados varieties, the differences are, to human perception, very slight.

With elaborate laboratory equipment it might be possible to determine whether slight differences in roughness or smoothness of surface play any noticeable part in regulating the number of eggs laid.

OVIPOSITION PREFERENCES.

In the absence of such laboratory facilities, attention was turned towards obtaining information in the field on the choice, if any, on the part of the moth for any particular *situation* on the cane blade for oviposition. During 1932 and 1933 therefore records were kept of the position in which *Diatraea* egg masses were deposited on cane blades; that is, whether deposited on the top surface, under surface, or mid rib.

Altogether 2912 egg masses were examined and recorded, and it was found that 1,957, or 67.2 per cent. of the egg masses were deposited on the top surface and 955 or 33.8 per cent on the lower surface. There is a very slight difference between the two surfaces, in that the lower surface appears under the microscope to be more regularly striated and slightly more even in texture than the upper; yet it is more than probable that the difference in numbers laid on the top surface is due to the fact that the moths are more likely to alight on the upper surface of the cane blade rather than deliberately to discriminate between the two surfaces.

This would appear to be supported by the fact that of the 1,957 egg masses counted on the top surface, 402, or 20.5% were deposited on the midrib, and 79.5% on the green leaf surface. Now the difference between the perfectly

* An experiment on these lines will be carried out in 1934.

smooth midrib, and the striated, slightly hairy leaf surface is greater than the slight difference between upper and lower surfaces: yet the proportion of eggs laid on the smooth midrib area is practically the same proportion as this midrib area bears to the green blade surface. That is to say, there would appear to be neither preference nor avoidance of either surfare, but each gets an average attention.

With regard to the under surface, of the 955 masses deposited, none were laid on the convex striated midrib, but 605 or 63.3 per cent were laid in the crease between midrib and blade; which is probably due to a preference for crevices shown by many insects when ovipositing. This preference for crevices is also shown on the upper surface of the blade, when that is crinkled or wrinkled, forming slight grooves in the general leaf surface. These grooves are invariably chosen for egg deposition.

There does not therefore appear to be any really definite or promising evidence of oviposition retardation or inhibition due to the tactile stimulus or structure of the leaf surface itself, which could be correlated with varietal susceptibility to moth borer, or probably be used in breeding work. This line of investigation will however receive further attention in randomised varietal blocks in 1934.

VARIETAL RESISTANCE TO BORERS.

There remains then the third factor of ease of larval feeding, penetration and survival.

That is to say, if one excludes for the present any varietal attraction and varietal leaf stimulus to egg deposition the question remains: does the variety of cane influence the *survival rate* of larvae, by rendering it easy or difficult as the case may be for newly hatched larvae to feed, and so to survive?

If it does, then on the present evidence the effect of variety on larval feeding and penetration is very likely to be the principal factor in causing the known differences in infestation in different varieties. Fortunately, a method exists of determining with a fair amount of accuracy a factor which is likely to govern the ease of larval feeding and penetration of canes. This method, used by Hazelhoff in Java (2) to determine varietal susceptibility to white top borers, is the determination of the percentage dry matter in the central, tightly rolled leaf sheath or spindle of the cane. Naturally the varieties to be compared must be examined at one time, because relative hardness or proportion of dry matter varies with the amount of moisture the plant has just received, and with the temperature. To obtain data by this method, on the varietal differences in dry matter ratio in the leaf spindle, and to compare this data with adequately determined varietal borer infestation figures, the following experiment was carried out.

Twenty leaf spindles were cut at random from 10 varieties growing in single rows alongside each other at Codrington Experiment Station, and each spindle was weighed in the field on chemical balances. This initial and vital portion of the experiment on which comparability of results depends, was carried through in the space of a few hours. When weighed (in weighed containers) the whole 200 spikes were then transported to the chemical laboratory for complete drying in proper apparatus, and for final weighing to determine percentage dry matter.

TABLE I.

VARIETAL RECORDS OF PER CENT. DRY MATTER AND PER CENT. BORER INFESTATION.

Leaf Spindle.	B. 891	B.417	B.726	B. 3063	Ba. 11569	P.O.J. 2878	B. H. (10) 12	B.2935	Co.281	B.3011.
1	15.83	20.17	17.28	19.82	14.43	19.87	20.53	20.67	20.38	24.89
2	17.13	17.01	20.32	17.11	19.48	17.99	19.90	20.90	19.52	20.18
3	20.77	19.64	17.52	18.99	21.55	17.52	15.10	19.62	19.06	20 66
4	17.25	16.85	17.96	16.32	18.15	19.79	19.29	19.87	16.60	19.74
5	15.40	18.50	17.13	15.33	20.02	20.37	17.39	19.92	19.75	19.60
6	16.99	18.63	17.29	15.49	16.80	17.85	20.66	19.51	21.17	19.64
7	19.31	17.11	15.64	19.20	18.13	...	19.39	20.49	20.47	21.20
8	16.32	17.15	17.61	20.15	17.93	18.82	19.52	20.71	20.82	18.09
9	15.23	16.95	15.90	17.46	15.13	17.90	19.49	22.79	21.52	20.06
10	16.87	15.74	19.58	20.35	19.81	19.51	19.84	19.62	19.56	18.86
11	16.82	18.86	17.70	15.62	19.73	19.91	21.04	20.87	20.58	21.33
12	14.72	17.10	17.81	18.77	18.86	17.85	20.12	15.30	19.83	20.31
13	16.53	16.81	21.03	18.62	20.28	18.05	19.22	18.51	19.07	20.44
14	17.22	17.21	19.46	18.09	17.93	18.87	19.41	19.80	17.99	19.74
15	16.17	17.63	16.91	16.86	20.96	17. 77	19.00	19.58	22.42	21.69
16	17.23	17.43	16.80	16.27	17.65	17.07	18.66	18.78	20.88	19.79
17	18.81	17.21	17.59	16.76	18.35	17.92	18.40	19.80	17.90	20.89
18	17.39	16.80	16.71	...	16.03	19.08	18.84	20.00	20.65	19.48
19	17.55	16.52	16.75	...	17.85	18.95	18.82	19.68	21.10	19.38
20	17.02	18.61	16.16	...	20.73	18.82	17.69	19.37	19.06	...
Mean	17.03	17.59	17.65	17.72	18.4	18.63	19.12	19.78	19.92	20.31
Borer Infestation 1933	18.68	High	14.26	Unknown	10.88	Very high	12.15	Low	Probably low	Unknown.

In the above table any difference of .93% or more between two means of 20 has a 20:1 chance of being a real one. Thus B.891 is significantly lower in dry matter in the cane spindle than are Ba.11569 or B.H.10(12) or B.2935. Similarly Ba.11569 is significantly lower than B.2935, and B.H.10(12) than B.3011.

The relative differences in dry matter content of cane spindles are more clearly shown by taking the highest standard Barbados variety, namely, B.H.10(12) as 100, and expressing other varieties in this proportion as in Table II below.

TABLE II.

DRY MATTER RATIO EXPRESSED IN TERMS OF B.H. 10(12) AS 100.

B. 891	B. 417	B. 726	B.3063	Ba. 11569	P.O.J. 2878	B. H. 10(12)	B.2935	Co. 281	B. 3011
89.0	92.0	92.3	92.7	96.7	97.4	100.0	103.4	104.2	106.2

There is also the possibility that not only does the resistance of the cane to early larval feeding and penetration, as measured by the above ratios of dry matter affect the initial survival of larvae, but the actual moisture content may be a factor to be considered. Moisture content is known to be the deciding factor in the survival of insects in stored produce such as maize, wheat, etc., and although it is not suggested that the moisture content of any cane spindle is below that necessary for larval survival, it is possible that the extra moisture content of B.891 for example plays its part in keeping very young larvae alive, almost equally as much as low fibre content facilitates the feeding and entry of these very young larvae.

The results set out above show that B.891, which is known to be a borer susceptible cane, has the lowest percentage of dry matter, and is therefore probably easy for young larvae to feed on, and to penetrate. B.417 which has the next lowest proportion of dry matter is also known to be a susceptible cane, but is grown on so small a scale that no joint infestation figures have been obtained for it. B.726, Ba.11569 and B.H.10(12) are in the order one would expect from field and factory work on their average joint infestation; similarly B.2935 which from present observations gives promise of being less susceptible than other Barbados varieties, is where one would expect it to be on the list of dry matter content.

The only exception is P.O.J.2878, which from all field records is a borer susceptible cane, and has a high percentage of joints infested (at least twice as much as Ba.11569 or B.H.10(12)) and yet comes midway between Ba.11569 and B.H.10(12) in percentage of dry matter.

Otherwise, it is possible to take the mean percentage dry matter figures in Table 1 and predict that Co.281, for which no joint infestation figures are

available in Barbados is likely to be borer resistant; and this would most probably be correct, because Co.213, for which infestation figures are available, is less susceptible and has fewer joints bored per cent. than any of the standard Barbados varieties. As Co.213 has a slightly greater percentage of noble strain than Co.281, it is fairly safe to say that Co.281 would at least, not be more susceptible to borer attack than Co.213, and would therefore be classed as a borer resistant cane.

With the two new Barbados varieties B.3063 and B.3011, neither of which has yet reached the commercial stage, the writer would feel quite justified from the figures in Table I in recommending that B.3011 be chosen in preference to B.3063, if one only of these two varieties could be taken for extended trial, and were other qualities fairly equal. From the dry matter ratio of B.3011, it would give promise of being very resistant to borer attack.

That variety of cane has a decided influence on extent of borer infestation, and most probably on level of moth population, is shown by the results of extensive plantings of B.891 in the 1931-33 crop. This new variety was largely planted in 1931 on account of its gumming disease resistant qualities, in place of the standard Ba.11569, which was susceptible to gumming. When the crop was reaped in 1933 and percentage borer infestation determined at 12 factories, the average percentage infestation at 9 of these factories where B.891 was being crushed was 18.68% joints bored, against an average of 10.88 per cent. for Ba.11569 at six factories where samples of this variety were still obtainable. The difference is sufficiently great to justify the opinion held by all planters who grew, and mill men who handled B.891, that this variety was invariably badly attacked by borers, and to justify the supposition that had the change over been persisted in and maintained on a large scale, that, in the absence of any control over *D. saccharalis*, the result would have been to raise the population level, and damage done by this pest, to a very dangerous level. As it happens, *D. saccharalis* is being kept under control by widespread and continuous colonisations of *Trichogramma*, and as a result, very few fields of B.891 reached their maximum borer infestation (which has been seen as high as 40—50% total loss), but they nevertheless reached a higher general average infestation than any other Barbados variety.

As stated by Cleare (1) in his paper on moth borer damage in relation to sugar cane varieties in British Guiana, cane varieites cannot be selected as suitable for general cultivation on their resistance to moth borer attack alone. Although Cleare rightly concludes that there are "indications that such resist- "ance is a character of the variety and possibly capable of transmission" no scientific workers have yet stated definitely what the characters connected with varietal resistance are. In the paper mentioned above, however, it is stated that "there appears to be a close relationship between the extent of moth borer "damage and the percentage of sucrose in the cane"; this is most probably quite correct, although the writer does not think that there is likely to be as close or as regular a correlation between borer susceptibility and sugar content, as between borer susceptibility and percentage dry matter in the leaf spindle. This percentage dry matter is also correlated with fibre content of the cane, and with what is generally known as "hardness" and "softness". Thus so far as Table I. goes, the canes of low percentage dry matter are both low in fibre content and high in sucrose, i.e., they are "soft" and "sweet"—

though again, softness as measured by dry matter or fibre content may not necessarily mean *lesser* hardness of rind. Moreover, it by no means always follows that a "hard," i.e., high dry matter ratio and high fibre content cane is low in sucrose percentage; nor that a hard rind cane will not be badly bored, seeing that young larvae can, and do, penetrate grown canes at the soft ring just above each internode or at the eyes of a joint, as well as at the soft terminal joints.

It would seem therefore, that as with most aspects of the moth borer problem, it is difficult to disentangle any one factor from numerous interlocking factors and conditions.

Nevertheless, percentage dry matter does seem to be sufficiently definitely correlated with moth borer resistance, that, within definite varietal classes such as Barbados varieties, or P.O.J. varieties, it can be used at any stage of cane growth to compare the relative borer susceptibilities of these varieties.

CONCLUSION.

From the foregoing discussion therefore it can be concluded that difference in varietal infestation due to difference in chemo-tropism for the adult moth is too difficult of measurement and determination to be of practical use, even if it exists to a measureable degree; and that difference in stimulation to oviposition due to specific roughness or smoothness of cane leaves is also so difficult of determination, and from the evidence so far available so very slight, that but little use can be made of it. There is at present no evidence that any variety exists, or could be bred, which would inhibit or sufficiently retard the deposition of eggs on its leaf surface.

There is, however, evidence that extent of borer infestation is correlated with the percentage of dry matter in the central spike, or leaf spindle, as determined by Dr. Hazelhoff for white top borer of cane in Java. The lower the percentage of dry matter in the leaf spindle, and therefore presumably the softer the cane tissues as a whole, the greater are the chances of survival of newly hatched larvae; hence, the greater the infestation. Conversely, the higher the percentage of dry matter, the fewer larvae succeed in feeding on or penetrating the cane tissues and consequently the greater the larval mortality and the lower the infestation.

It is suggested therefore that this factor of high percentage of dry matter in the leaf spindle, is the one which should be made the criterion for determining susceptibility to moth borer attack, and that it should be considered as a desirable quality to breed into canes.

REFERENCES.

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2. Hazelhoff, C. H. —Investigations on the White Top Borer—Int. Soc. Sugar Cane Technologists, Fourth Congress, San Juan, Porto Rico. March, 1932, Bull. No. 66.